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REPORT No. 1

(Belgium, France, Italy, Portugal, Spain and their Colonies and Switzerland)

ON THE QUESTION OF THE USE OF CONCRETE AND REINFORCED CONCRETE ON RAILWAYS (SUBJECT I FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By Mr. JULLIEN,

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and

Mr. CLAISE,

DIRECTOR IN CONTROL OF WORKS ON NEW LINES AND OF RAILWAY TRACK AND BUILDINGS AT THE FRENCH MINISTRY OF PUBLIC WORKS.

Figs. 1 to 36, pp. 19,7 to 2007.

A. — Study of the different types of concrete sleepers.

HISTORY.

The question of the use of reinforced concrete sleepers was the subject of several reports at the Ninth Congress of the International Railway Association held in Rome in 1922 and the following conclusion was finally arrived at : (1)

« In regard to railway equipment, it is desirable that the results of trials which are being carried out by various administrations of the use of reinforced concrete sleepers should be recorded. The

(1) This question runs as follows : « The use of concrete and reinforced ooncrete on railways.

A. — Investigation into the respective merits of the different designs of concrete sleeper.

B. — Concrete and reinforced concrete buildings.

(2) Translated from the French.

(1) See *Bulletin of the Railway Congress*, August 1922 number, p. 1117.

latter may form a valuable adjunct to the supply of wooden sleepers and in that will help to regulate their price. »

The various reporters had shown that trials made up to that time had met with little success, especially those carried out by the Italian State Railways, where 300 000 reinforced concrete sleepers originally put into use on their main lines had had to be taken up and laid in station yards.

At the same time one of the reporters dwelt on the more encouraging results which had been obtained in France with the Vagneux and Calot sleepers. He pointed out that from thenceforward the different types of reinforced concrete sleepers ought to be reduced to two.

In the first (as in the Vagneux and No. 123 Italian State Railways sleepers) the sleeper is formed by two large supports under the rails connected by a transverse tie.

In the second (as in the Calot sleeper and No. F. S. 2323 of the Italian State Railways), the sleeper is regarded as a beam receiving the rail load and transmitting it to a ballast of varying elasticity.

It will be shown that this classification applies in all cases and that all the new sleepers tested come under one or other of these headings.

It will be noticed that in 1922 the reporters who dealt with this question suggested improvements which have since been carried out :

Substitution of a hard wood treenail for the cast iron bush used in the Calot sleeper to take the coach screw;

Interposition of a wooden packing between the sleeper and the bottom of the rail;

Complete suppression of tamping under the centre portion of the sleeper.

The interest that is taken in this question by the various Railway Administrations, is shown by the numerous replies which we have received. It will be seen that the results obtained up to date are most encouraging.

* * *

Replies have been received from the following Administrations who have carried out trials with reinforced concrete sleepers :

North of Spain Railway, Italian State Railways, Swiss Federal Railways, the principal French Railways, Algerian State Lines, the Paris, Lyons & Mediterranean Railway (Algerian lines), the Tunisian Railway Company, the Dakar-St. Louis Railway, the *Société des Transports en Commun de la Région Parisienne*, the East of Lyons Tramways, the Chalosse and Béarn Tramways.

In the table below are classified the various types of sleepers tried by each Company : when more than thousand were tested the type is *in italics*.

Railway.	TYPES OF SLEEPERS.	Date laid.	Number of sleepers tested.
North of Spain.	1st type	1902	36
	2nd type	1924	Under three pairs of rails.

Railway.	TYPES OF SLEEPERS.	Date laid.	Number of sleepers tested.
Italian State.	*F. S. XI 5º*	*1907-1913*	*300 000*
	Engineer Lolli	*1917-1918*	*2 000*
	F. S. 1918	1920	50
	Giordani	1922	3
	Valeri « longitudinal sleeper (oscillating) type ».	1922	7
	Sani Bonaventura	1923	12
	F. S. 1918 modified	1923	31
	Gasparini	1923	3
	Valeri « longitudinal sleeper (fixed) » 1st type	1923	11
	Ekabag	1924	26
	Cascione	1924	5
	Valeri « longitudinal sleeper (fixed) » 2nd type.	*1925* being made.	*1 000* 7 500
	Tramways of Milan	1926	200
	King's	1926	18
	F. S. 1925 pot sleepers	being made.	*170 000*
Swiss Federal Railways.	*Swiss Federal Railways, original type*	*1910-1918*	*1 000*
	Swiss Federal Railways, modified type	since 1918	490
	Vagneux with Swiss Federal Railways fastening.	1924	390
	Vagneux body	1924	21
French Railways.			
Alsace-Loraine.	Ess	1908-1911	34
	Vagneux	1924	390
	Vagneux body	1924	21
Paris-Girdle.	Vagneux mixed type	1922	208
	Vagneux body	...	...
Est.	Vagneux ordinary	1922	80
	Vagneux mixed type	1922	*1 200*
	Vagneux mixed type	in use.	*2 500*
	Vagneux body	1922	55
	C. O. T., R. A. B.	*in use*	*5 000*
	Calot	1924	110
State.	Vagneux ordinary	...	...
	Vagneux mixed	...	...
	Calot, Paris-Orleans type	...	...
	Calot, Nord type	...	...
Midi.	Orion	1926	130
Nord.	*Calot modified*	*since 1926*	*41 550*
	Calot (pot sleepers)	*since 1926*	*10 200*
	Vagneux mixed	*since 1926*	*7 350*
	Vagneux (pot sleepers)	*since 1925*	*2 150*
	Vagneux body	*since* 1925	500
	Gaudin, Orion, S. E. L.	...	.

Railway.	TYPES OF SLEEPERS.	Date laid.	Number of sleepers tested.
Paris, Lyons & Mediterranean.	*Vagneux*	...	*24 000*
	Michel	...	...
Paris-Orléans.	*Calot*	*since 1909*	*140 000*
	Gaudin	1920-1925	110
	L. H.	1924	...
	Calot pot sleepers	...	*60 000*
Algerian State.	Vagneux, mixed	1927	28
	Vagneux, bodies	1927	6
	Vagneux, pot sleepers	...	34
Paris, Lyons & Mediterranean (Algerian Lines.)	*Vagneux*	...	*1 600*
Tunisian Railway Company.	Seguela	1910	14
	Vagneux	*1927*	*1 200*
Dakar-St.-Louis.	Sarda	...	...
Soc. des Transports en commun de la Région Parisienne.	*Vagneux mixed*	1927-1928	*1 000*
	Camargue type	1927-1928	600
	Gaudin type	1927-1928	100
	Gérard type	1927-1928	500
East of Lyons Tramways.	Special type	...	38
Chalosse and Béarn Steam Tramways.	Orion	1927	100

The replies of the above railways to the detailed questionaire sent them are summarised below in the order in which the questions were put.

Analysis of the replies to the questions.

I. — *Types tried.*

The drawings given in the Appendix to this report show the principal types of reinforced concrete sleepers which are or have been tested on rather a large scale.

II. — *Types withdrawn.*

Most of the Railways have not definitely abandoned any one type of sleepers. This is because in actual fact it is not a question of testing a sleeper put forward in its final form, but of a development assisted by trial and it may happen that a sleeper, which at the outset gave bad results, after improvements, shown by the first unfortunate trial to be necessary, becomes technically satisfactory. The

types of sleeper which have been completely withdrawn seem to have been abandoned in the majority of cases, through failure to develop them or for reasons of policy and not because experience had really and definitely condemned their original design.

With the above reservations, attention must be drawn to the fact, that the Italian State Railways have withdrawn many types, which on trial did not give satisfactory results. The Paris-Orleans Railway has abandoned the Gaudin and the Liébeaux-Hennebique types, in order to concentrate on the perfection of the Calot sleeper; the French State Railways have withdrawn the Vagneux sleeper consisting of two blocks joined by a tie of armoured concrete, the Alsace-Lorraine Railways have abandoned the Ess sleeper which developed cracks, the Tunisian System has abandoned the Seguela ; the French West African Railways only tried the Sarda and have abandoned it, and lastly the *Société des Transports en Commun de la Région Parisienne* appear likely to retain the Gérard sleeper alone as it has given them satisfaction up to the present and is less costly than other types tested.

III — *Types retained.*

The North of Spain Railway has since 1924, obtained good results with the one type of sleeper they have tested but they consider that the small number of sleepers in service does not prove that the type is definitely acceptable.

The Italian State Railways after trial of several types of sleeper, have, since 1925, concentrated on the sleepers known as « Longarine fisse Valeri » and « Blochetti F. S. 1925 », but the trials are too recent to give a final judgment.

The Swiss Federal Railways, have, since 1924, gained good results with 390 sleepers of the Vagneux type with a modified rail attachment.

Three of the principal French systems, the Nord, the Paris, Lyons & Mediterranean and the Paris-Orleans have been the only railways who have used for several years, large numbers of reinforced concrete sleepers. The Paris, Lyons & Mediterranean uses the Vagneux exclusively, the Paris-Orleans the Calot, while the Nord uses both the modified Calot and the Vagneux sleepers.

The Nord and the Paris, Lyons & Mediterranean have not altogether given up certain other types which they have had under the test and continue to put on trial new types which are put forward and appear interesting. At the time when these Railways sent us their replies they had in service :

41 550	sleepers	Modified Calot type.
10 200	pot sleepers	
7 350	mixed sleepers	Vagneux type.
2 150	pot sleepers	
500	joint frames	

The Paris, Lyons & Mediterranean had in service 24 000 Vagneux sleepers and although these appear up to now to be technically satisfactory the inventor continues to try out new improvements notably with regard to the rail fastening.

The Paris-Orleans Railway has 140 000 Calot sleepers on its lines and their reply to the queries is as follows :

All the types of sleeper originating from the Calot have given us satisfaction; but we have only retained in production, sleepers having the following proportions *viz.:* 300 kgr. (660 lb.) of cement to 400 l.: (0.52 cubic yard) of sand and 900 kgr. (1 985 lb.) of fine gravel, having treenails for the rail attachment and

which have great powers of resistance without being too costly.

These types have given complete satisfaction in the straight and in curves of a minimum of 500 m. (25 chains) radius. For curves of smaller radius laid with Vignoles rails, rapid wear of the outside stop of the wooden packing between the rail and the sleeper takes place, and soon after laying causes a gradual widening of the gauge which increases till it reaches a total of 6 to 8 mm. (1/4 to 5/16 inch) after which it remains constant. We have no yet discovered a remedy for this, but the matter is being looked into.

Since 1922 we have been using large numbers of reinforced concrete sleepers on our secondary lines, 140 000 or about one tenth of the total number in service, being in use.

IV. — *Recent introductions.*

Several Railway Companies including some of those who are using reinforced concrete sleepers in large numbers, have reported on new types which are worthy of attention, or that they are considering new designs.

The Swiss Federal Railways draw attention to the Lössl sleeper; the French Nord, to the Henriquet; the Est, to the Collet and the Paris, Lyons & Mediterranean to the Stent.

From this the conclusion must be drawn that even if certain types of sleepers now give satisfactory results, the period of development is far from being at an end.

V. — *Service conditions (speed, number and weight of trains; nature of ballast).*

The opinions expressed on this question have been extremely divergent which may be explained in this way : Certain Railways have indicated that they have imposed certain limiting conditions when using reinforced concrete sleepers, but without wishing to assert that they were imposed because of the types of sleeper used. If in certain cases a limiting condition has been definitely imposed for a known drawback, no defect has been revealed which by suitable improvements appears impossible to cure.

A certain number of lines are practically confining the use of reinforced concrete sleepers to secondary lines, recognising nevertheless that certain trials on the main lines have given good results, others are giving up hard ballast and others large size ballast, while others do not use reinforced concrete sleepers on curves of small radius; but these do not appear to be unchangeable conditions absolutely and it can be said to sum up that if certain Railways have limited the conditions under which reinforced concrete sleepers can in practice be used they have done so for reasons of prudence or policy or because of defects in the types tested. Up to now there appears to be theoretically no reason why the concrete sleeper should not take the place of the wooden sleeper in all cases.

VI. — *Price delivered at site; cost of maintenance.*

The information given to us as to the cost of the different types of reinforced concrete sleepers is very varied. This is not to be wondered at. The costs given are for sleepers manufactured or purchased more or less recently and therefore naturally made up of varying unit prices.

It is difficult too, to compare the cost price of two sleepers, one of which contains 140 kgr. of concrete, the other 275 kgr. or of one which contains 16 kgr. of steel, the other, 25 kgr. The cost price

depends above all else on the number made. Trial sleepers made in small quantities, or even several dozen at a time offer no reliable information on this subject.

Finally whilst the price given by a manufacturer is a firm price, it is very much more difficult to work out such a cost price, when the sleeper is made by the railway company, in a works already busy with other forms of concrete construction; the general charges, amortization and taxes, etc., become not only difficult to assess but impossible to compare.

As an example, we would point out that according to an estimate which was given us in November 1928, the cost price of the Vagneux sleeper would be 55 frs.

The French Administrations state that at the present time the price of a wooden sleeper (oak or beech) varies in different districts, and according to the quantity of creosote used, between 35 and 56 frs.

In a general way it can be said that the first cost of a concrete sleeper is considerably more than the wooden sleeper, but it may be expected that a line sleepered in reinforced concrete, will cost less to maintain and last longer.

It is therefore possible that in the end the cost of concrete sleepers per annum will work out to be neither more nor less than the wooden one.

As yet, however, one of the items in the calculation, the life of the concrete sleeper, is still unknown.

The economic side of the question cannot be fully appreciated until a sleeper of a perfected design and more satisfactory from the technical point of view is evolved. The many types put on test, some of them quite recently, seem to indicate that the question is in the evolution period in spite of a number of solutions considered locally, and no doubt provisionally as satisfactory.

VII. — *Methods of calculation.*

No method of calculation has been reported to us. Indeed the calculations for a concrete sleeper are not easy; even if the moment of inertia for a sleeper is taken as constant and the ground as homogeneous, hypotheses usually far from true, the calculations are still extremely difficult.

The stresses are extremely difficult to arrive at since they are not purely statical but are rather rapidly changing stresses or shocks.

Calculations do not appear likely to give any very valuable results on this question whilst it is relatively simple and much more certain to carry out actual tests on sleepers in the road.

VIII. — *Inspection tests.*

Most of the Railways, including those who have used large numbers of reinforced concrete sleepers, have made no arrangements for inspecting sleepers of their own manufacture or purchased.

The French Est makes an inspection by breaking a number of sleepers and examining the reinforcing bars and the quality of the concrete : the Nord, the Est and the French State Railways have carried out tests on the rail attachments by means of the extractometers which have to stand a pull of 5 tons.

IX. — *Laboratory tests.*

Up to date only actual service in the road has been accepted as determining the value of a sleeper. The drawbacks of this method are that it renders it almost impossible to improve the original design

of a sleeper because it takes several years to confirm the result of the smallest modification.

To remedy this drawback the Paris-Orleans Company has designed a test machine by means of which tests can be carried out on the sleepers six months after manufacture. The experiment consists in applying to the sleepers, by means of an hydraulic press, stresses, comparable in direction and intensity with those which would be actually met with in service.

The pressures exerted and the deflections of the sleeper in the plane of application of the load, are registered on a cylinder making one revolution every 58 seconds. This apparatus shows the amount of stress and deflection at any moment of the test.

The pressures can be varied from 0 to 30 kgr. par cm^2 (427 lb. per sq. inch), of ram area which corresponds to a total pressure of 0 to 19 tons at the point of application. Deflections of 37 mm. (1 29/64 inches) can be dealt with.

Tests are carried out on both end and center sections.

To test the centre section, the sleeper is placed on two knife edges, spaced from 1.11 m. to 1.51 m. (3 ft. 7 3/4 in. to 5 ft. 11 in.) symmetrically with the section and pressure is exerted on the lower side of the sleeper. For tests of the end sections, pressure is applied to the upper face, the knife edges set symmetrically in relation to the section being brought to a spacing of 0.785 m. (31 inches).

Local crushing of the concrete is avoided by inserting steel plate of suitable size between the sleeper, the point of the ram and the knife edges. The diagrams obtained are as shown below.

The concrete cracks in the part under tension before the maximum moment is reached, but these cracks although quite large do not impair its strength. When an attempt is made to increase the moment the deflection increases, the sleeper always carrying the maximum moment. The limits of the machine prevent the sleeper being broken, but with deflections of 4 cm. (1 9/16 inches), the knife edges being placed at 0.78 m. (30 3/4 inch) centers and with cracks of 1 cm. (13/32 inches) within the part under tension, the sleeper supported the maximum moment, the concrete under compression not cracking as a rule. The presence in the track of slightly cracked sleepers does not therefore present any danger and further the bushes and treenails did not suffer during the breaking tests of the sleeper ends, the break always occurring outside the sections situated in line with the bushes and treenails so that the strength of the fastenings is not endangered.

X. — *Laying.*

Beyond the general precautions taken to prevent breakage and chipping of the concrete, no special precautions are laid down as regards reinforced concrete sleepers, except in the case of the Calot; all the lines employing this type excavate a trench midway between the rails so that the sleeper shall not be packed under its centre. Some authorities forbid packing with rammers, others permit the practice subject to certain precautions.

Tamping by shovel and the placing of the sleepers on a properly levelled bed are generally recommended.

XI. — *Special cements and steels.*

All kinds of cement have been used without any one of them having given results either markedly good or bad.

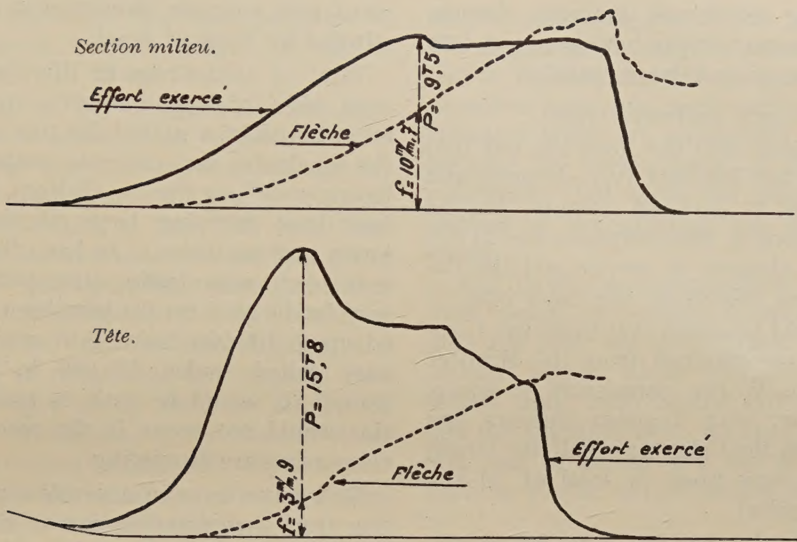


Fig. 1. — Diagrams of tests on sleepers.

Explanation of French terms : Effort exercé = Load applied. — Flèche = Deflection. Section milieu = Centre section. — Tête = End Section.

Quick setting cements in particular, have in certain cases given bad results which suggests some particular fragility but in other cases the results have been satisfactory.

High tensile steels have not been used.

XII. — *Extension of the use of reinforced concrete sleepers.*

The question put was as follows.

« Do you, at the present time, propose to extend the use of reinforced concrete sleepers on your lines, and, if so, why ? »

The diversity of the replies received on this subject, show the uncertainty which still prevails.

One line alone, the French Nord, in view of the possible saving in maintenance and in the longer life expected from the reinforced sleeper, are at present extending their use. All the other lines are continuing trials on a more or less large scale, but having in mind the high first cost of the reinforced concrete sleeper, and still finding it possible to obtain wooden sleepers without much difficulty, do not appear to be systematically extending their use, but are waiting for more conclusive results from the tests in progress.

The Paris-Orleans Railway which, with the object of reducing the labour and upkeep has during the last few years largely extended the use of reinforced sleepers, has announced that under present conditions of higher cost of manufacture and of laying as compared with the wooden sleeper, it has been compelled to restrict developments in this direction.

Is it possible to employ large numbers of reinforced concrete sleepers under all conditions ?

The facts given above go to prove that there has been substantial progress in

perfecting reinforced concrete sleepers and that certain types have been put into service on quite a large scale.

The French Railways report :

That since 1925 the Nord has put into service 7 350 Vagneux type sleepers, and since 1926, 41 550 Calot sleepers; that the Paris, Lyons & Mediterranean has 24 000 Vagneux sleepers in service and the Paris-Orleans 140 000 of the Calot type.

It should be added that these two Companies have obtained from the Minister of Public Works, permission to equip, the former with Vagneux sleepers, the latter with the Calot type, half the length of three new lines (a total of 70 km. = 43.5 miles).

On the other hand it must be remembered that the 140 000 Calot sleepers in use on the secondary lines of the Paris-Orleans under light traffic have behaved well except on curves of less than 500 m. (25 chains) radius especially with Vignoles rails. The Paris-Orleans are about to lay 3 000 sleepers on an electrified part of the line where the trains reach speeds of 110 km. (68.3 miles per hour and the axle weights of the locomotives are 19.5 t. (19.2 Engl. tons).

If there should be any doubt as to the possibility of substituting concrete sleepers for wooden ones in a few years time, the facts as above stated and the encouraging results of the trials made compel one to recognize that very marked progress has already been made.

Meanwhile the period of test is not yet at an end. Although certain French lines now use concrete sleepers in large numbers, the multiplicity of types in use and under test and the variety of results obtained does not permit us to conclude that the problem is technically solved or that on all railways without distinction, reinforced concrete sleepers can be substituted for those of wood.

First of all as regards life, the trials even when of large numbers, appear to be of too short a period for one to form the conclusion that concrete sleepers will have a very long life on all lines, including those carrying large numbers of heavy express trains. As has often been pointed out when testing other permanent way details good results have been obtained up to 100 000 trains, but many tests have failed under 150 000 to 200 000 trains. It would be rash to assert that this would not occur in the case of the sleepers we are discussing.

Still as we have in concrete a material free from such deterioration as is caused by rot in wooden sleepers, and as wear of concrete like that of steel sleepers will only be caused by the passage of trains, one can take it that, as with the steel sleeper, their employment will be above all justified on secondary lines and in the colonies. Indeed for such lines experience leads us to hope that the reinforced concrete sleeper will have a longer life than the wooden one. Coming to the cost at site, the Paris-Orleans Administration holds that the wooden sleeper has the advantage in price over the reinforced concrete sleeper, but the investigations made by this line seem to show that by installing a works for mass production on a large scale in the neighbourhood of a river, from which supplies of sand and gravel could be taken without transport costs it would be possible to reduce the cost of the concrete sleeper below that of the wooden one.

This conclusion has not yet been confirmed by experience, but as a result of the indications given above, one may assume that the price of a reinforced concrete sleeper is about 55 fr. whilst the

French Railways find that the price of a creosoted wooden sleeper in oak or beech is from 35 tot 56 fr.

Again, in the comparisons that have been made between the respective merits of the two types of sleeper, the longer life of such sleepers and the smaller quantity of ballast required therewith have been brought into account. On the first point, and for reasons which have just been given it is evidently too early to form conclusions. On the second point, and bearing in mind that the types of concrete sleeper so far used are similar in outside dimensions to the wooden sleeper, one cannot understond why the same ballast profile is not used for the wooden as for the concrete sleeper.

As against this and keeping in view the experience over five years on a line belonging to the Paris-Orleans on which all the sleepers are of the Calot type, there is reason to estimate on a saving in maintenance costs.

Under these conditions and in view of the condition of the iron, cement, wood and creosote markets it does not appear unreasonable to hope that *from the point of economy*, it would be of advantage to use reinforced concrete sleepers on secondary lines, the extra price, delivered at site, being compensated for by a longer life and a saving in the cost of upkeep.

It is however impossible to come to a definite conclusion on the subject of the employment of this type of sleeper on lines which carry heavy, fast and numerous trains. It is on such lines that experiments should be continued. One is justified in thinking that if all the required precautions are taken there would be no objection to such experiments on the grounds of safety.

Taking another point of view, is it possible to fix the arrangement of details of one or several types of the sleepers? We do not think so. We must be content to indicate that certain types, which moreover have only been perfected after laborious trials, are satisfactory, not only because the arrangement of details is satisfactory but above all because the method of manufacture has been perfected.

And likewise as concerns both the technical design, of reinforced concrete sleepers and their use in the track, there are certain points which should undergo longer trials, such as the rail fastening and the question as to whether the kind and size of ballast and the method of packing should not be looked into.

CONCLUSIONS.

Of the numerous types of reinforced concrete which have been tried, a certain number have been abandoned, many again have been in use too short a time to permit of a definite opinion being expressed, certain types, however, have been extensively used on lines with light traffic notably those of the French Railway Companies.

Reinforced concrete sleepers have begun to be used on lines with heavy traffic at fairly high speeds, but these trials have not been under way long enough for any definite conclusions to be formed.

The question remains more or less open as regards their use on lines carrying heavy, fast and numerous trains and it is on such lines that trials should be continued.

The price delivered on the work is higher for the reinforced concrete sleeper than for that of wood, but it is hoped that on lines with light traffic the increased price will be compensated for by longer life and lower maintenance. Ex-

periments should be undertaken dealing with the methods of rail attachment and on the advantages and drawbacks of the various kinds of ballast from the point of view of the life of the sleepers.

APPENDIX.

Principal types of reinforced sleepers which have been tested on a large scale :

a) Valeri longitudinal sleeper;

b) F. S. 1925, pot sleepers;

c) Swiss Federal Railways sleeper;

d) Orion sleeper;

e) Gérard sleeper;

f) « Société des Embranchements Industriels » sleeper;

g) « Société Coopérative des Travaux en Béton armé » sleeper;

h) Gaudin sleeper;

i) Henriquet sleeper;

j) Vagneux sleeper;

k) Calot sleeper.

a) Valeri longitudinal sleepers.

The Italian State Railways have laid 1 km. (0.62 mile) of the line between Orte and Chiusi with sleepers of the design shown in the print (fig. 2) below, and formed of two longitudes stayed together by two iron bars.

The results have so far been satisfactory, except on a very clayey section; the trials are continuing.

b) F. S. 1925 pot sleepers.

The Italian State Railways have put on test a number of reinforced concrete pot sleepers connected by a flat steel tie bar. The coach screws engage with a steel spiral cast in the concrete.

Several thousand pairs of blocks laid in the lines of important termini have so far given satisfaction and 170 000 pairs are in course of manufacture.

c) Swiss Federal Railways sleepers.

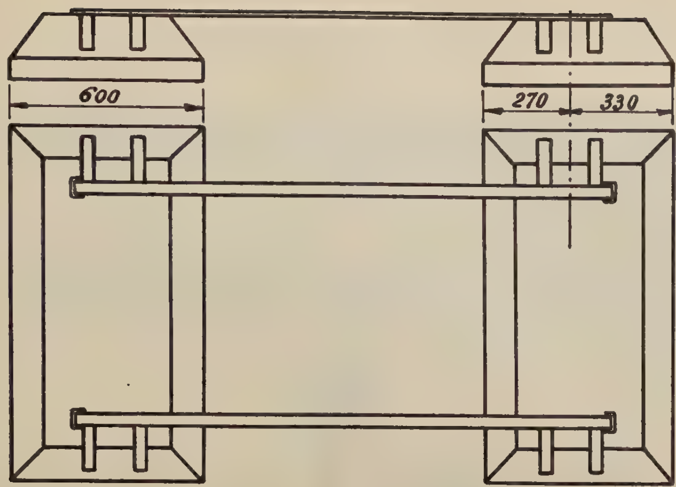
The sleeper tested by the Swiss Federal Railways is reinforced longitudinally by rods and transversely by a sheet of expanded metal in the shape of an inverted U. The rail is fastened to a steel sole plate 11 mm. (7/16 inch) in thickness by bolts and clips and this plate in turn rests on a packing piece of poplar 20 mm. (13/16 inch) thick. The assembly is fastened to the sleeper itself by hook bolts passing through a tube cast into the sleeper. The heads of these bolts engage in a steel recess sunk in the underside of the sleeper. Up to date they have behaved well. They were laid in lines carrying heavy traffic near stations at which all trains stop without any special care as regards the kind of ballast but with a space left clear at the middle of the sleeper.

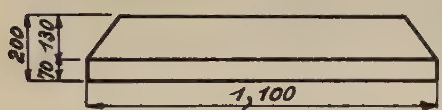
j) Vagneux sleeper.

The Vagneux sleeper has been the subject of extended trials on the various French lines and is in current use on many of them.

For normal lines the type which appears likely to survive is that known as the « composite » type. It consists of two blocks connected by an I beam of standard section which is better adapted to stand the bending stresses set up in this part by the passage of trains than one in reinforced concrete.

The French Est Railway in 1928 laid 2 500 sleepers of the type shown in the print, figure 11, in a line with a large and heavy traffic.

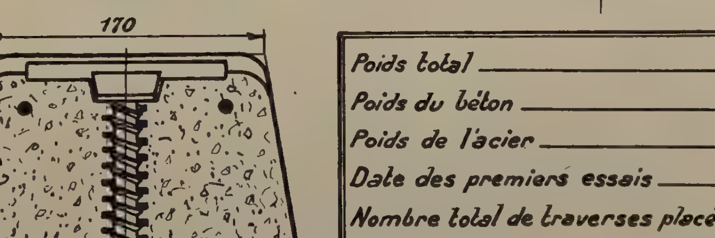


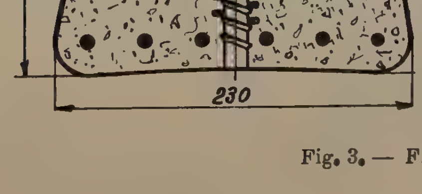


Poids total	,,
Poids du béton	,,
Poids de l'acier	,,
Date des premiers essais	1925
Nombre total de traverses placées sur les voies	1000
Nombre de traverses restant actuellement en service	1000

Fig. 2. — Valeri longitudinal sleeper.

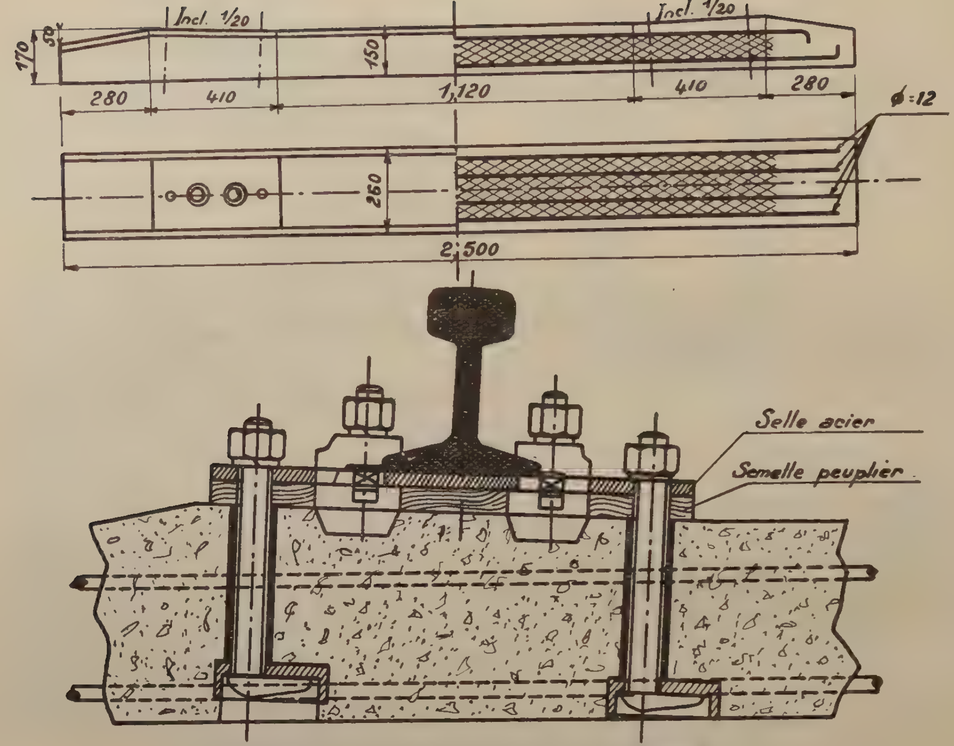
Explanation of French terms in the table (figs. 2 to 11 and 14 to 16):
Poids total = Total weight. — Poids du béton = Weight of concrete. — Poids de l'acier = Weight of steel. — Date des premiers essais = Date first tested. — Nombre total de traverses placées sur les voies = Total number of sleepers laid in the track. — Nombre de traverses restant actuellement en service = Number of sleepers now remaining in service.





Poids total	,,
Poids du béton	,,
Poids de l'acier	,,
Date des premiers essais	1926
Nombre total de traverses placées sur les voies	,,
Nombre de traverses restant actuellement en service	,,

Fig. 3. — F. S. 1925 pot sleepers.



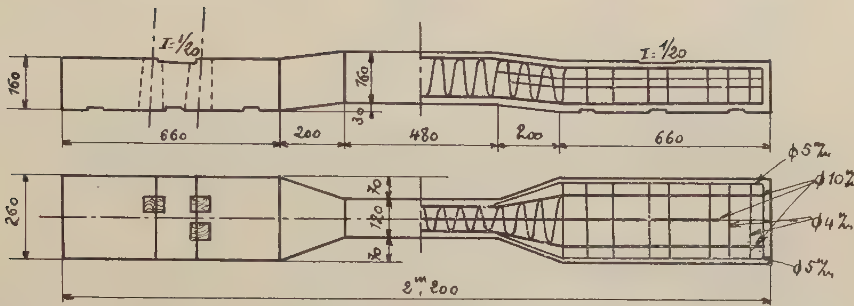
Poids total	254 k
Poids du béton	233 k
Poids de l'acier	21 k
Date des premiers essais	1921
Nombre total de traverses placées sur les voies	300
Nombre de traverses restant actuellement en service	300

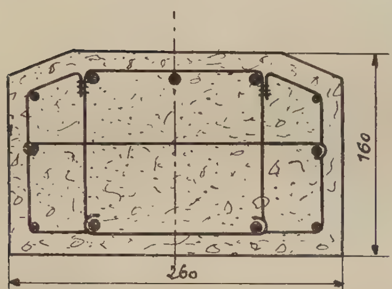
Fig. 4. — Swiss Federal Railways sleeper.

Explanation of French terms :
Incl. 1/20 = Inclination 1:20. — Selle acier = Steel sole plate. — Semelle peuplier = Poplar packing piece

The fastening of the rail to the sleeper has been modified at various times. Originally the rail rested on a hard packing of a wood or metal sole plate and was kept in place by coach screws with short necks screwed into a Thiollier spiral embedded in the concrete. This attachment offers considerable resistance to pulling out but called for specially and carefully gauged screws so as to prevent cracking of the concrete in line with the holes. In addition, as reported by the

d) **Orion sleeper.**

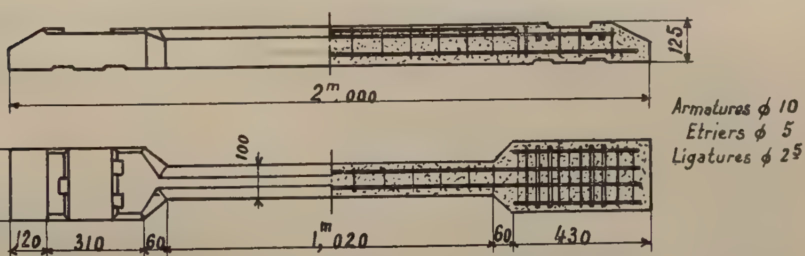


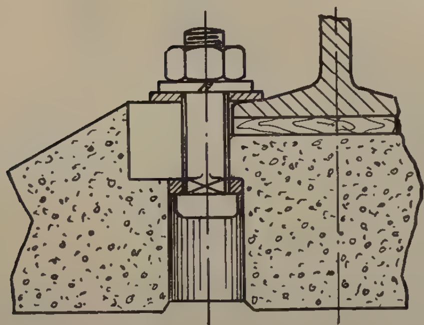


Poids total	180 K
Poids du béton	164 K
Poids de l'acier	16 K
Date des premiers essais	1926
Nombre total de traverses placées sur les voies	130
Nombre de traverses restant actuellement en service	130

Fig. 5.

e) **Gérard sleeper** (for tramway lines — S. T. C. R. P.).





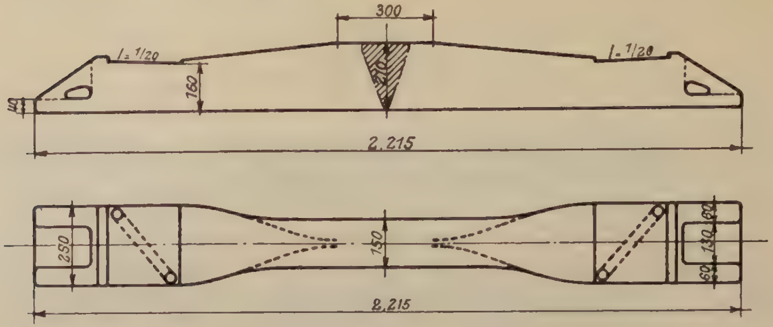
Poids total	"
Poids du béton	"
Poids de l'acier	"
Date des premiers essais	1927
Nombre total de traverses placées sur les voies	500
Nombre de traverses restant actuellement en service	500

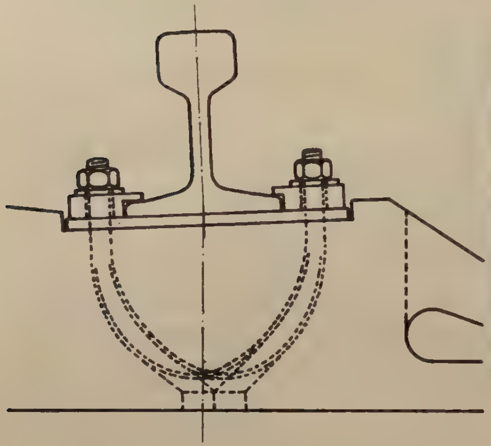
Fig. 6.

Explanation of French terms.

Armatures... = Reinforcement 3/8-inch diameter. — Etriers... = Loops 3/16-inch diameter. = Ligatures... = Binding wire 3/32-inch diameter.

f) « Société des Embranchements Industriels » sleeper.

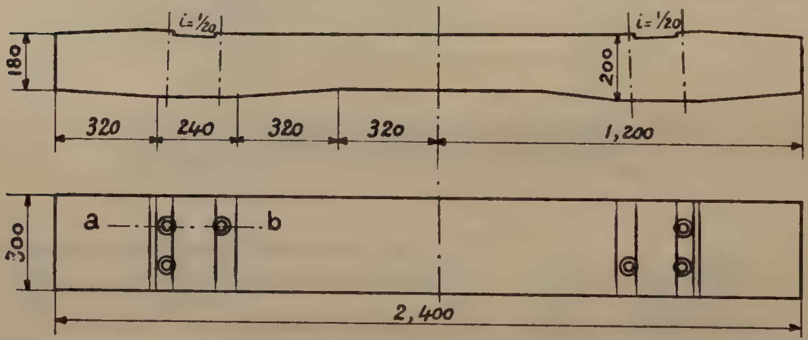


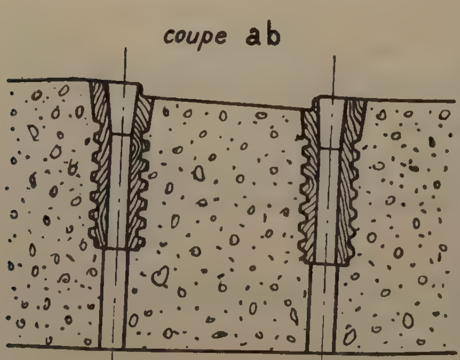


Poids total	,,
Poids du béton	,,
Poids de l'acier	,,
Date des premiers essais	,,
Nombre total de traverses placées sur les voies	,,
Nombre de traverses restant actuellement en service	,,

Fig. 7.

g) « Société Coopérative des Travaux en Béton armé » sleeper.

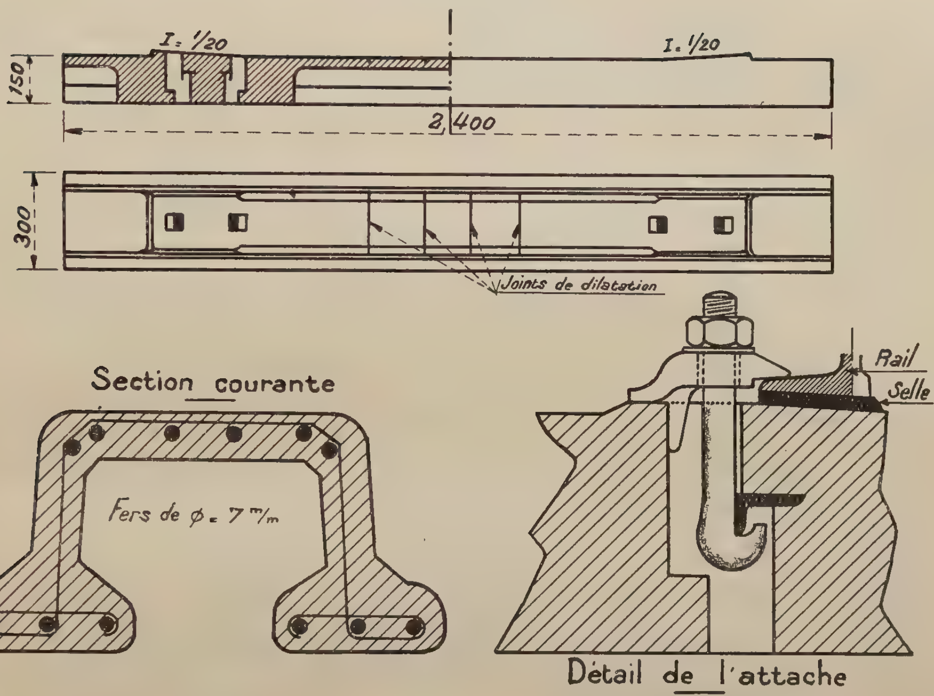


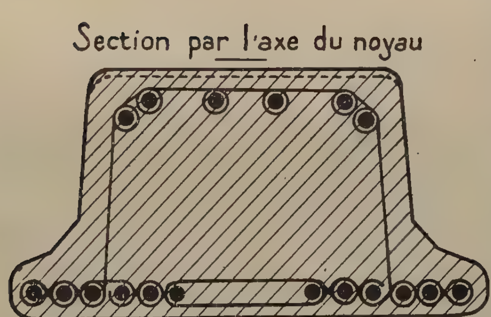


Poids total	,,
Poids du béton	,,
Poids de l'acier	,,
Date des premiers essais	1928
Nombre total de traverses placées sur les voies	5000
Nombre de traverses restant actuellement en service	,,

Fig. 8.

h) **Gaudin sleeper.**





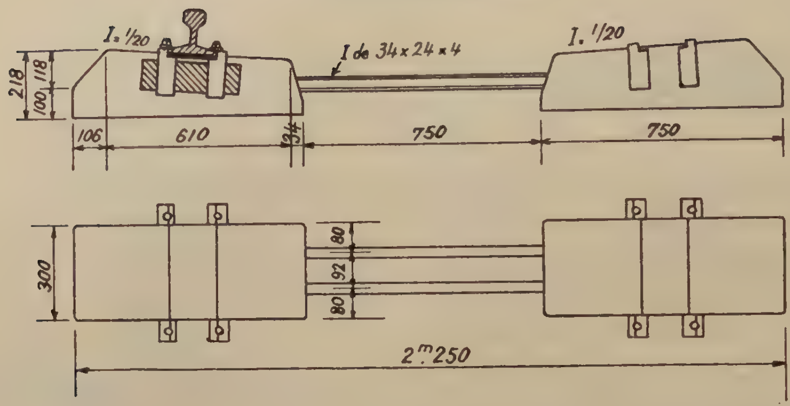
Poids total	160 K
Poids du béton	139 K
Poids de l'acier	21 K
Date des premiers essais	1924
Nombre total de traverses placées sur les voies	»
Nombre de traverses restant actuellement en service	»

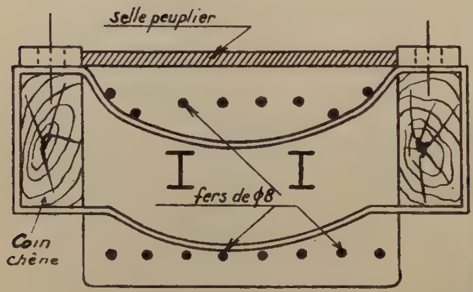
Fig. 9.

Explanation of French terms : Détail de l'attache = Detail of fastening. — Joints de dilatation = Expansion joints. — Section courante = Normal section. — Section par l'axe du noyau = Section through the centre of the solid part.

Société des Transports en Commun de la Région Parisienne, especially, when the sleeper is not recessed at the supports, the collar of the coach screws, the head of which bears only on one edge (that is against the foot of the rail), bends in the

i) Henriquet sleeper.





Section through a reinforcement.

Poids total	,,
Poids du béton	,,
Poids de l'acier	,,
Date des premiers essais	,,
Nombre total de traverses placées sur les voies	,,
Nombre de traverses restant actuellement en service	,,

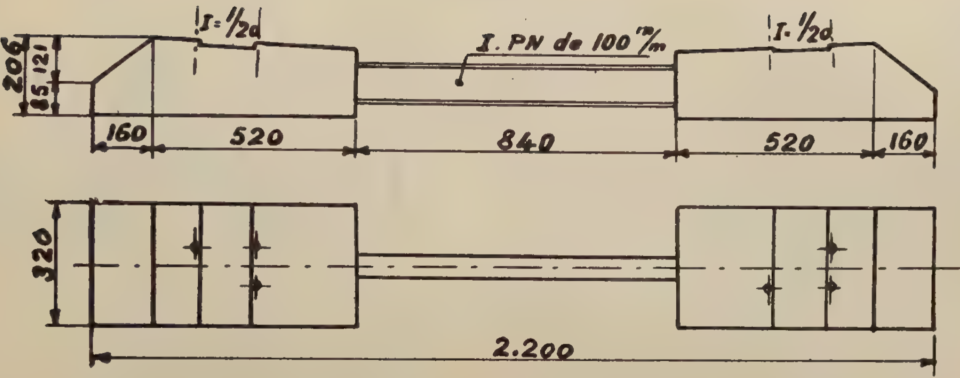
Fig. 10.

Explanation of French terms : Coin chêne = Oak wedge. — Selle peuplier = Poplar packing piece.

neck when any attempt is made to tighten it up.

In order to get a better fastening, tests have been made with a coach screw bolt with clip. The head of the bolt was made like a coach screw. At the top it was squared and the clip fitted over. When the nut is tightened down the clip holds the rail and sleeper together. This arrangement holds better and remains tight longer than the first design but it was more costly and the difficulty of screwing the coach screws into the spiral fitting remains. To remedy these defects and to make the sleepers non-conducting, a method using a shouldered wooden ferrule was tried, but did not give the expected results as regards holding down.

The fastening which up to date has given the greatest satisfaction is that which consists of a hard wood ferrule screwed into a Thiollier spiral fitting. The coach screw is of the normal type and is screwed into the ferrule as into a wood sleeper. The resistance to pulling out offered is very great and it remains tight; the renewal of the ferrules is easy with simple appliances, the sleepers do



Poids total	208 k
Poids du béton	188 k
Poids de l'acier	20 k
Date des premiers essais	»
Nombre total de traverses placées sur les voies	»
Nombre de traverses restant actuellement en service	»

Fig. 11. — French Est Railway. — Composite sleeper, Vagneux system.

not act as conductors and the rails can be insulated. The old type of fastening is however still used and the Paris, Lyons & Mediterranean do not consider the new type as final. The kind of wood for the packing under the rail is not yet decided; compressed poplar, elm, creosoted oak and teak have given good results as a general rule.

Some Railways are already using large numbers of Vagneux sleepers. The Paris, Lyons & Mediterranean and the French State Railways only use them with small ballast. The French Nord Railway which does not use special ballast with these sleepers, has found a saving of 0.100 m³ of ballast per metre (0.12 cubic yard per yard) of road over that required for wooden sleepers.

The Vagneux has also been tried on narrow gauge lines. On such lines the bearing plate sleeper has behaved better than on standard gauge lines and it is used at the same time as the composite sleeper. In the meantime the Algerian lines of the Paris, Lyons & Mediterranean who are considering the laying of a large number of Vagneux sleepers on the metre gauge have chosen the composite type (fig. 14) with the coach screw and Thiollier spiral fitting fastening. This Administration believes that the use of Va-

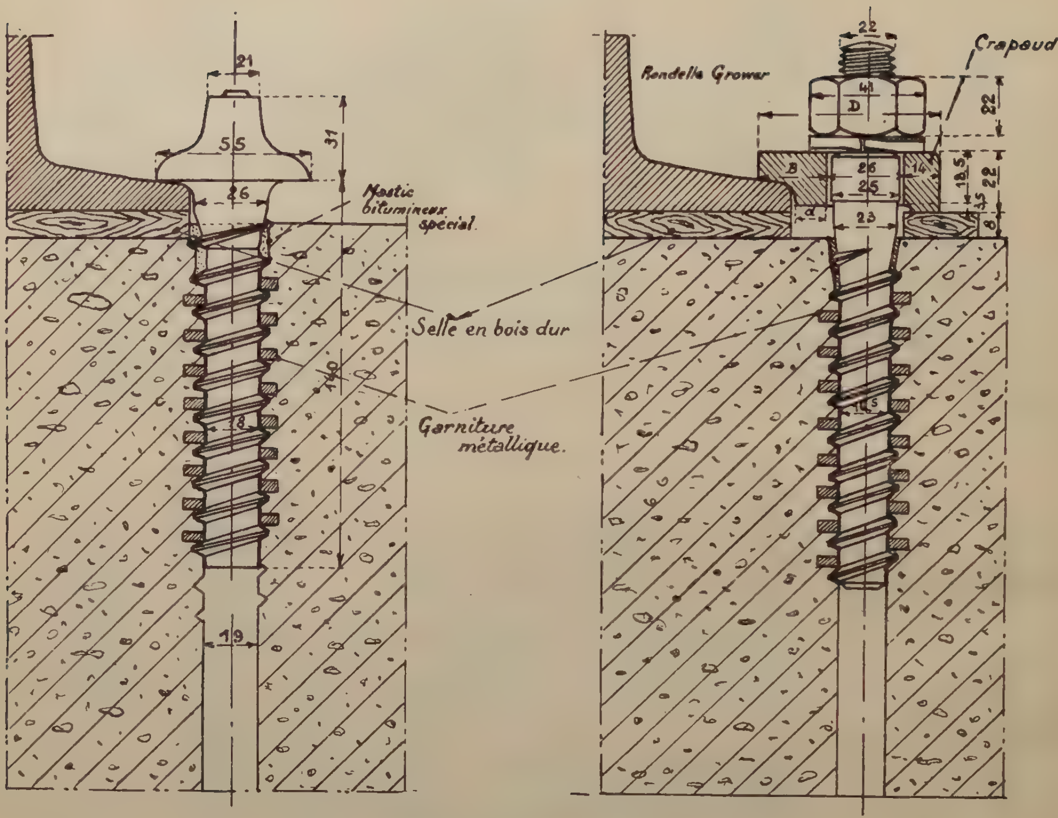


Fig. 12. — Rail fastening on Vagneux sleeper.

Explanation of French terms : Crapaud = Clip. — Garniture métallique = Steel spiral. — Mastic bitumineux spécial = Special bituminous mastic. — Rondelle Grover = Grover washer. — Selle en bois dur = Hard wood packing piece.

gneux sleepers will save ballast because the sleepers need not be covered over, an arrangement impossible in Algiers with wooden sleepers owing to the frequent fires which occur.

k) Calot sleeper.

In France the Calot sleeper has been under test on the Orleans line for many years. The French Nord Railway while retaining the principle of fastening by means of a cast iron bush, is making a large sleeper intended for use on lines over which express trains run.

The general design is shown in the drawing (fig. 15) : the longitudinal reinforcement much reinforced under the rails is completed by iron straps.

The considerable weight of this sleeper will be noted and it is therefore difficult to handle. The French Nord Railway lays them by means of cranes carried on wagons and so arranged that five sleepers at once can be put in their final position. This method makes it easy and cheap to lay them. Packing is carried out by shovel or pick and levelling by the edge of the shovel.

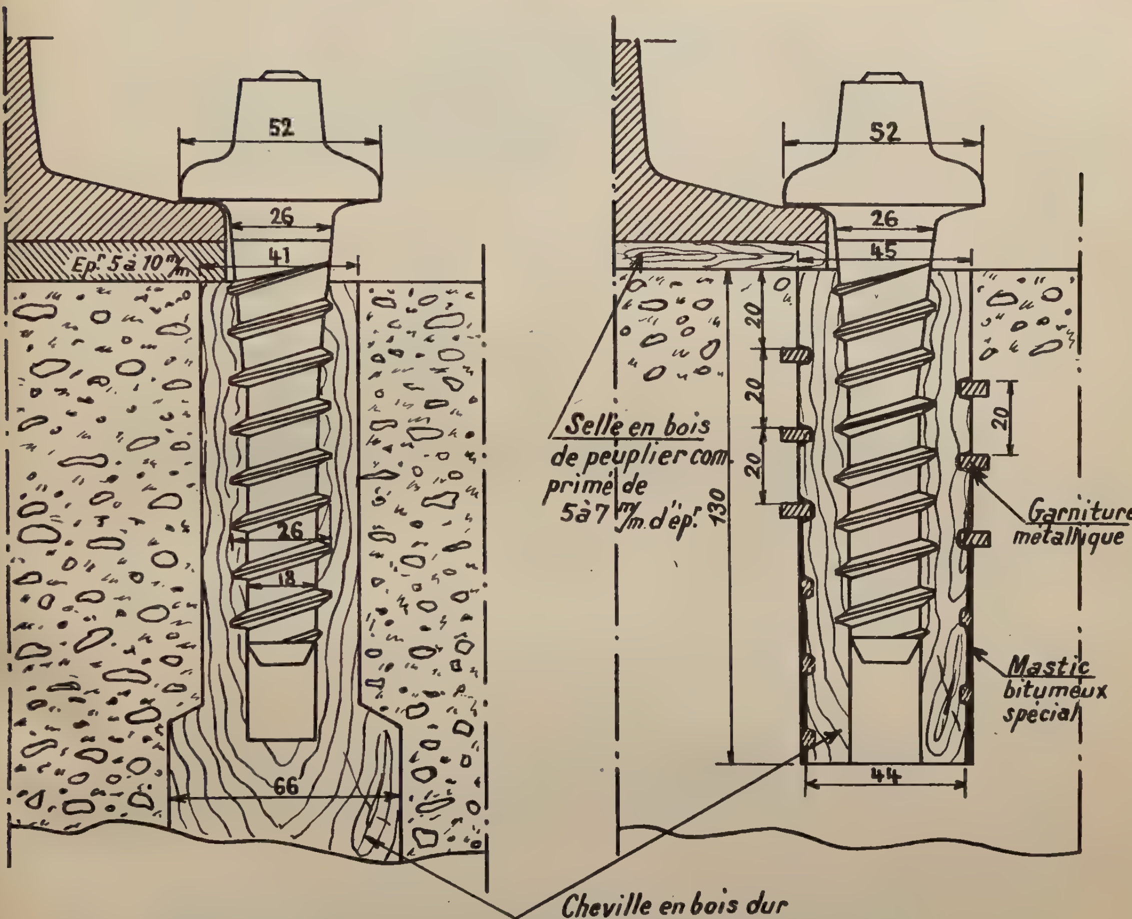


Fig. 13. — Rail fastening on Vagneux sleeper.

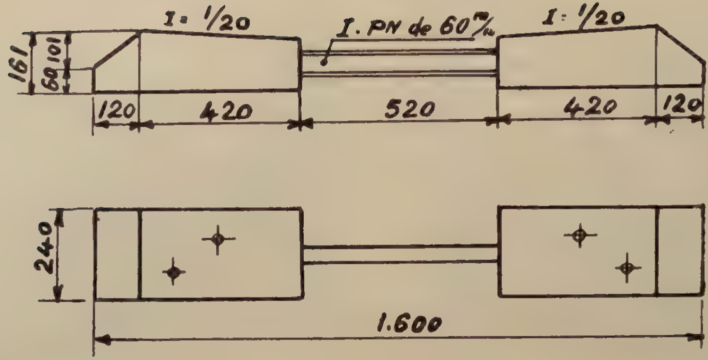
Explanation of French terms : Cheville en bois dur = Hard wood ferrule. — Garniture métallique = Steel spiral. — Mastic bitumeux spécial = Special bituminous mastic. — Selle en bois de peuplier comprimé... = Compressed poplar packing piece, 13/16 to 9/32 inch thick.

By excavating a trench along the centre of the track the breakages of the sleepers which often occurred at first have been prevented. The State Railways and the Paris-Orleans who use Calot sleepers have also had to open up the centre of the sleeper by stopping the packing at a distance of 0.35 m. (1 ft. 1 3/4 in.) from the rail.

The slight additional labour is largely compensated for by the ballast saved; on the French Nord where the ballast is stopped half way up the sleeper the saving in ballast when using Calot sleepers instead of wood is 0.400 m³ per metre (0.48 cubic yard per yard) of road.

Thanks to greater care in getting the coach screws and ferrules ready, the Nord Railway has not had the same trouble as the Paris-Orleans on which it was sometimes necessary to retap the ferrules in place before the coach screws could be entered.

The Paris-Orleans Railway has just



Poids total	36 k
Poids du béton	"
Poids de l'acier	"
Date des premiers essais	"
Nombre total de traverses placées sur les voies	"
Nombre de traverses restant actuellement en service	"

Fig. 14. — Vagneux sleeper for metre gauge.

made a pattern of Calot sleeper for fast roads laid with standard Vignoles rails of 46 kgr. (92.7 lb. per yard) similar to the Nord sleeper although with a lighter longitudinal reinforcement but with an entirely new type of fastening.

The Calot ferrule used to date forms a very strong fastening, but the sleepers fitted with it are good conductors of electricity and cannot be used with track circuiting. It was whilst trying to find a sleeper which was a bad conductor, that the Paris-Orleans Railway was led to introduce a new method of fastening which is now used on all sleepers made at the Périgueux works. A steel mandrel with a projecting thread is placed in the sleeper mould at the proper point for the coach screws. 24 to 48 hours after casting (according to the season) the mandrel is screwed out leaving a hole with a perfectly regular thread. When the sleeper is dry a creosoted hornbeam treenail (fig. 17) is screwed into the hole.

When screwing a coach screw into this treenail the wood is driven into the concrete and when tested by means of the extractometer it is found that the resistance is always greater than that of the same coach screw in an oak sleeper. It is possible to remove the

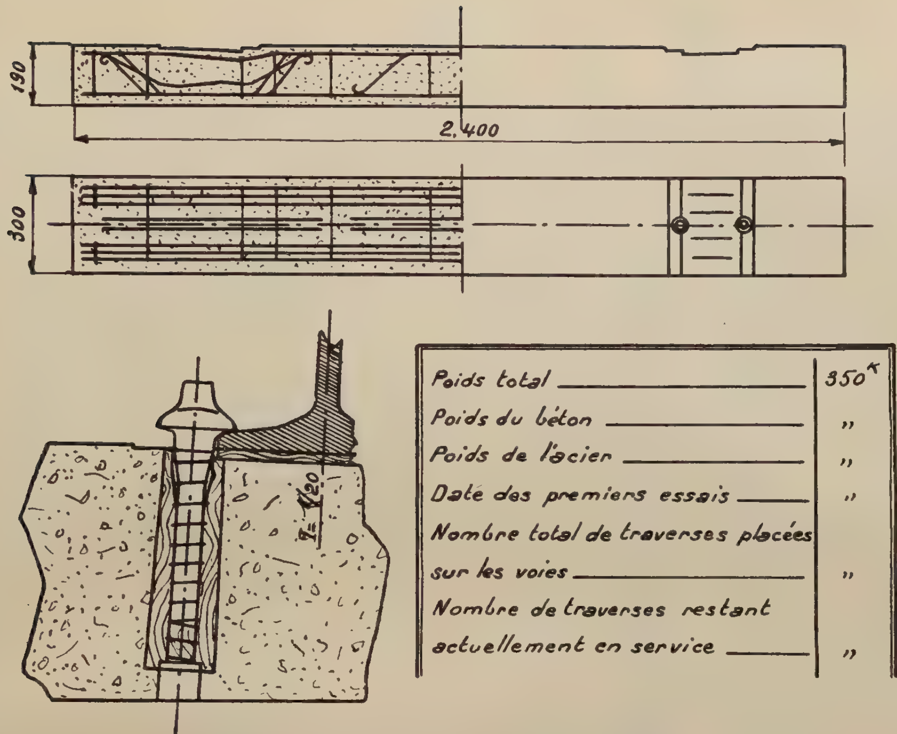


Fig. 15. — Calot sleeper (French Nord Railway).

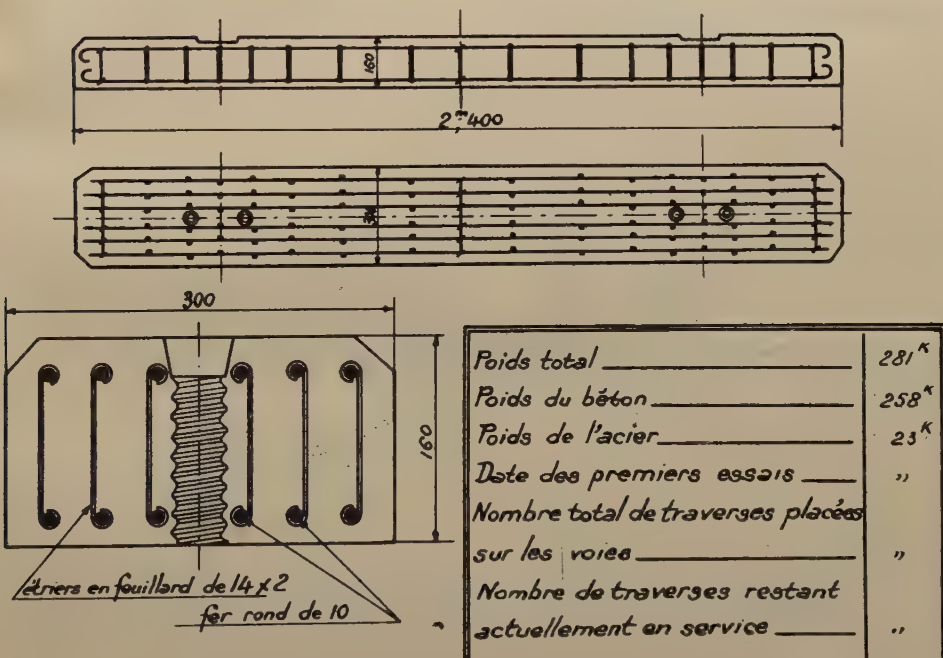


Fig. 16. — Calot sleeper (Paris-Orleans Railway).

Explanation of French terms : **Etriers en feuillard... = Strap irons in 9/16 × 5/64-inch strip. — Fer rond de 10 = 3/8-inch round steel bar.**

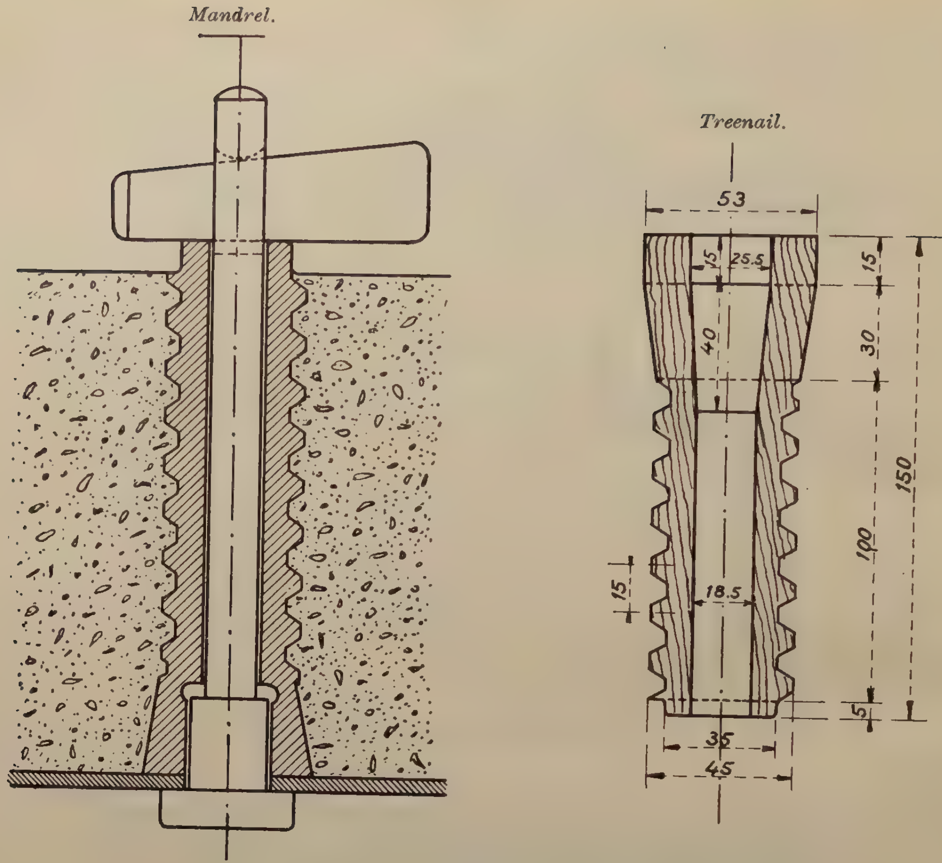


Fig. 17.

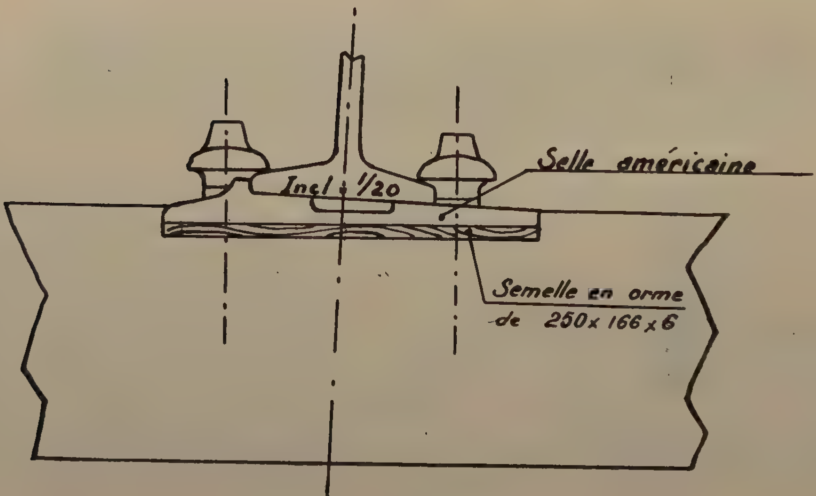


Fig. 18. — Arrangement for holding the track to gauge.

Explanation of French terms.

Selle américaine = American sole plate. — Semelle en orme = Elm packing piece.

coach screw with the aid of a special and very simple tool without injuring the threads in the concrete and screw in another; this may be done up to five times, the resistance to pulling out being invariably satisfactory. The first sleepers with this new design of fastening have been in the track for eighteen months and have behaved perfectly.

The Paris-Orleans Railway has been obliged to replace the poplar packings under the rail by elm 6 cm. (2 3/8 inches) thick which will last one or two years this device will prevent spreading of he Tapered packings are employed on curves but in spite of this precaution the results have not been very satisfactory and spreading of the rails on curves of small radius to the extent of 6 to 8 mm. (1/4 to 5/16 inch) has taken place.

To put a stop to this spreading the arrangement shown in figure 18 is being tried on three hundred sleepers.

A steel sole plate with a rib against which the outer édge of the rails bears is placed under the rails; between the steel sole plate and the sleeper an elm packing is interposed. It is hoped that this device will prevent spreading of he rails.

B. — Buildings, etc., in concrete and in reinforced concrete.

The use of ordinary concrete and of reinforced concrete on the railway was the subject of a number of reports to the Congress of Washington in 1905 and of Rome in 1922. The conclusions of the full assembly of this latter Congress brought out the value of using ordinary concrete and reinforced concrete for overbridges, buildings, workshops, locomotive sheds, etc.

The result of the enquiry that we have just made, shows that no important modification has taken place since the Rome Congress in the art of building with this material.

As regards underbridges, the special reporter of the Rome Congress Mr. W. W. Grierson, proposed the following conclusions :

« The suitability of reinforced concrete « for railway underbridges has yet to be « demonstrated, other possibly than for « quite small spans; for larger spans, its « adoption must at present be approached « with caution » [1].

The full meeting, however, adopted the following conclusions [2]. « For railway bridges which are subject to dynamic forces, there appears to be no technical reason against the use of reinforced concrete, which can frequently be used advantageously, but requires very close supervision in its execution. »

In this present report we have endeavoured more particularly to bring out the progress that has been realised in construction work in concrete, reinforced or not, underbridges.

We have considered the benefits that the use of quick setting cement or other special cements, and the use of high tensile steel, could give.

We have also studied new methods of construction; use of pin joints to reduce secondary and parasitic stresses; the introduction of systematic deformations before striking the centres or when doing this work.

Finally we have called attention to the various methods used to protect the concrete structures against the action of smoke and fire.

We have made full use of the very valuable and complete information that the undermentioned Railway Companies have been good enough to send us :

Spain :

Madrid to Saragossa & Alicante Railway.
North of Spain Railway.

Belgium :

Belgian National Railway Company.
Nord-Belge Railway Lines.
National Light Railway Company.
Lower Congo to Katanga Railway Company.

Italy :

Italian State Railways.

Switzerland :

Swiss Federal Railways.
Rhætian Railway.

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(1) See *Bulletin of the International Railway Congress*, April 1922, page 652.

(2) See *Bulletin of the International Railway Congress*, August 1922, page 1117.

France :

The eight main Companies.

The Landes Railways.

The Algerian Lines of the Paris, Lyons & Mediterranean Co.

The Tunisian Railways.

The French West African Colonial Railways.

The Franco-Ethiopian Railways, from Djibouti to Addis-Abeba.

The Smyrna-Cassaba & Extension Railway.

The Indo-China & Yunnan Railways.

As an appendix to the present report, we give a short description of the principal railway bridges in concrete, or in reinforced concrete recently built or under construction (bridges over the Nicoba, the Najerilla, the Sambre, the Renory viaduct, the Chienti bridge, the viaduct over the Great Siva Valley, the Grandfey viaduct, bridges on the Marne, on the Cère, on the Meuse, Plougastel viaduct and the Caille bridge) and an important overbridge, the Lafayette bridge in Paris.

Special cements and steels.

Ferro-cements. — Although exclusively used until recent years, the ordinary Portland cement, is now replaced under certains conditions, by special cement, known as ferro-cement, which has amongst other features, that of hardening quickly and of showing great strength. The result of its use is to make large savings in shuttering, in addition owing to the heat released during setting, it is possible to continue the work during frost.

In using « ciment fondu » or ferro-concrete for the construction of various works, certain of which were underbridges, the Alsace-Lorraine, Nord, Paris-Orleans, as well as the Smyrna-Cassaba and Extension Railways, have not had in view only its rapid hardening,the strength of the material being sensibly the same as that taken when using artificial Portland cement.

The Paris, Lyons & Mediterranean Railway have used « ciment fondu » for the construction of a road bridge with straight bearers above the Culoz to Modane line, at the station of Modane-Fourneaux in order to be able to continue the works during the winter. Special precautions had to be taken when carrying out this work; they are described in an article published in the *Revue Générale des Chemins de fer*, of March 1927, and summarised as follows :

« In order to prevent any alteration through contact with other cements or lime, the « ciment fondu » was kept in a special store. In addition, all the equipment used, including the mixing floor, were very carefully cleaned.

« This material was used in the same way as artificial Portland cement, and in the same quantities, noting however, that in order to get a thoroughly plastic concrete, a rather greater quantity of water is required than with other cements. »

« Ciment fondu » not being very binding, the faces on which the concreting was restarted, were always very carefully cleaned and the ramming of the concrete was very carefully done.

All materials before being used were raised above freezing temperature, the mixing water being heated to a temperature of 15 to 18° C. (59 to 64.4° F.).

The shuttering was freely swilled down with hot water to free it from frost, all necessary precautions being taken that water did not lodge anywhere thereon as concrete made with « ciment fondu » runs away quickly in water.

While setting, the concrete of the girders protected by the shuttering on three faces was immediately covered over on the top surface by a double layer of sacks pressed well together so as to form a good insulation. The concrete of the flooring which was not so well protected as the above, was carried out in sections 4 m. (13 ft. 1 1/2 in.) wide perpendicular to the centre line of the structure. The object of this arrangement was to divide the flooring into parts each of which could be carried out in a single day's work and immediately as finished, covered over with a layer of straw 15 to 20 cm. (6 to 8 inches) thick, protected in turn by a tarpaulin.

The Paris, Lyons & Mediterranean Railway also carried out tests of strength on pieces of concrete made in the yard during periods of frost. Similar tests were also made while concreting the bridge. The whole of these tests was completely satisfactory. Further tests have shown that even when of small thickness the temperature of the concrete is sufficient for it to acquire an appreciable strength before falling to the atmospheric temperature, and consequently, to prevent it being effected by frost. *From these experiments it would appear that concrete made with « ciment fondu » can be used when of a thickness of 20 cm. (8 inches) at a temperature of — 15° C. (5° F.).*

With blocks of considerable thickness such as for piers and abutments, certain supplementary precautions have to be taken, as has been shown by the experiments carried out by the « Société des Chaux et Ciments de Lafarge et du Teil » and described in the *Revue Générale des Chemins de fer* of October 1926.

It was found quite accidentally, that the ouside of the pillars in concrete made with « ciment fondu » was much harder than the interior. Experiments made have given similar results. When carried out on tubes measuring two metres each way, one of concrete using Portland cement, the other of concrete with « ciment fondu », it has been found: for the first cube that the hardening of the centre was sensibly equal to that of the surface : for the other cube a hardening of the centre definitely inferior to that of the surface.

This is a fact not yet definitely explained, but which must be fully taken into account in cases where it is necessary to build thick blocks of concrete with « ciment fondu ».

It appears desirable to carry out the work in layers 50 cm. (20 inches) thick, each layer not being laid upon the preceeding one, until the latter has had at least three days in which to set.

When building the Plougastel bridge, near Brest, it was also noted that when using « ciment fondu » the setting of the concrete was not always normal (see in this connection two articles published in the *Génie Civil* of the 12th of March 1927, and the 11th of August 1928).

These experiments, and these observations, suffice to show the need for taking special precautions when using « ciment fondu », if it is desired to take full benefit of its remarkable properties in complete security.

Super cements. — In addition at the present time there are Portland cements which harden rapidly and which can to some extent be substituted for « ciment fondu »; these special cements have been used by the Swiss Federal Railways, the Smyrna-Cassaba and Extension Railways, and the great French Railways.

The French Est Railway has recently used uper cement when building an overbridge, the Lafayette bridge, at Paris, which was opened to traffic in

1928. The concrete consisting of 350 kgr. (770 lb.) of cement, 0.8 m³ (1.046 cubic yard) of small gravel and 0.4 m³ (0.523 cubic yard) of sand had to give a strength of 250 kgr. per cm² (3 556 lb. per sq. inch) at the end of twenty eight days.

Some of the Railway Companies have sent us particulars of the strength that they allow when using concrete made with super cement. The table below gives these values for the ordinary mixtures.

RAILWAYS.	Strength per cm² (per square inch) from a mixture of :		
	300 kgr. (660 lb.).	350 kgr. (770 lb.).	400 kgr. (880 lb.).
	Kgr. (lb.)		
French Est	...	75 (1 067)	85 (1 209)
French Midi	70 (996)	...	...
French Nord	..	...	70 (996)
Paris, Lyon & Mediterranean	70 (996)	80 (1 138)	90 (1 280)
Paris-Orleans	70 (996)	...	...

High tensile steel. — In order to give structures considerable strength and at the same time reasonable lightness, use has occasionally been made not only of super cement, but also of high tensile steel.

For this reason the French Est Railway used steel of 30 kgr. (19.05 Engl. tons per sq. inch) elastic limit when building the Lafayette bridge; the calculations however were based on an elastic limit of 24 kgr. so that the factor of safety was increased by 25 %.

The Paris, Lyons & Mediterranean Railway uses, when building columns for carrying high tension over head transmission lines, semi-hard steel embedded in cement of high strength. The working strength required is 18 kgr. per mm² (11.43 Engl. tons per sq. inch), the breaking strength being 55 to 64 kgr. (34.92 to 40.63 Engl. tons per sq. inch) and the minimum extension at fracture being 18 %.

Recent improvements in the use of concrete and of reinforced concrete.

During recent years, the technique of concrete and of reinforced concrete has been improved by new methods of construction of which the railway companies have profited. We give below some information on the improvements made in the method of using concrete, on the progress accomplished in making the shuttering and finally the modern methods of striking the centres and for reducing parasitic stresses.

In concrete and reinforced concrete structures, resistance depends to a large extent upon the homogenity and the proper handling of the materials used. On very large works the railway companies have added to the present tensile and compression tests, so as to be certain of the quality of the cement, deflection tests with the object of making certain of constant plasticity and of the suitable

addition of water. This has checked the tendency of contractors to use very liquid concrete which is easier to make and use, but which gives lower strength. In this way when building the Lafayette bridge, over the French Est Railway line the proportions of cement was considerably increased in places where the amount of reinforcement used made it necessary to use a more fluid concrete. Care was also taken to get a well rammed concrete, so that this could be better done, while pouring and settling, pneumatic rammers were used both on the shuttering, and on the reinforcement. Thanks to these precautions, a much more homogeneous and much stronger concrete was obtained than that of buildings constructed in the usual manner.

Furthermore it is possible to reduce the risk of fissuration of the concrete due to defective assembly or to the bad condition of the timber used for the shuttering by giving the construction of the shuttering special attention, and by using steel shuttering when the number of similar parts to be made is sufficiently great. In this connection metal shuttering was used when building the arches of the Renory viaduct, for standard gauge [9 arches in concrete of 61.4 m. (201 ft. 5 3/8 in.) and and one arch of 34 m. (111 ft. 6 3/4 in.) span] which consisted of four trellis work arches with three pin joints strongly wind braced.

It is, however, on wooden centering that the large railway bridges described in the appendix have been built :

Bridge over the Sambre [reinforced concrete arch with two pin joints 64 m. (209 ft. 11 3/4 in.) span];

Bridge at Neuilly-sur-Marne (reinforced concrete arch with pin joints 64 m. of span);

Boncourt bridge over the Meuse [arch in stirruped concrete without joints, of 42 m. (137 ft. 9 1/2 in.) span];

Bridge over the Elorn at Plougastel [cantilever arches in reinforced concrete of 180 m. (590 ft. 6 3/4 in.) span];

La Caille bridge, over the Usses river [cantilever arches in concrete of 137.5 m. (451 ft. 1 1/2 in.) span].

These examples show that it is now possible to construct in concrete or in reinforced concrete, railway bridges in arches of large span and of various designs. Various systems of joints are available, either in stirruped concrete (Sambre, Neuilly-sur-Marne) or metal (Renory) able to transmit the enormous thrust developed. There is a tendency to give the preference to arches with two, or without any joints, but various methods have been tried to get rid of, when building, the parasitic stresses which are necessarily set up. For example, the arch when being set out is given systematic deformation which will compensate to a large extent the possible parasitic defects to be feared. This method, the first important application of which was made to the Villeneuve-sur-Lot road bridge [arches in ordinary concrete of 90 m. (295 ft. 3 3/8 in.) span], has been used when building the railway bridges over the Sambre, of Boncourt, over the Meuse, of Plougastel, over the Elorn. It consists in opening by means of jacks, a joint arranged near the crown, and to lengthen thereby the neutral axis. The elastic condition thus obtained is maintained by introducing into the gap a plate in concrete strongly reinforced, and covered with pure cement, at the same time slightly releasing the jack. The amount that the joint should be opened, and the angular deflections that its two faces are given, are so determined as to cause elastic stretches practically compensating a

Fig. 19. — Overbridge at Laon.
(French Nord Railway.)

Fig. 20. — Pentice roof at the Paris-Austerlitz goods station.
(Paris-Orleans Railway.)

large part of the parasitic stresses. It is even possible to go a little further and compensate part of the stresses due to the permanent load and to the live load. In addition, opening the key joint determines the amount the arch will be raised above the centre.

The operation of striking the centre, thus becomes quick and easy, several hours being sufficient to separate the arches from their shuttering in the bridges mentioned above.

This method has not been limited to large arch bridges; it has also been used in other constructions where parasitic stresses are of great importance.

The French Nord Railway has provided over the lines in the station at Laon, a suspension bridge entirely in reinforced concrete (see photograph, fig. 19) which consists of two spans of 37.1 m. (121 ft. 8 3/4 in.). The dead weight of the bridge, and its live load, would have caused, if special precautions had not been taken, an extension of the cables which would have resulted in a

bending of the stiffening girders capable of causing the latter to crack. In order to reduce the extension when removing the shuttering, the cables have been extended after the bridge was concreted, by raising their bearings several centimetres. The cables and their supports were subsequently concreted in. The ultimate deformation of the bridge was in this way reduced to permissible values.

In the same manner, the pentices of the new parcels office at the Paris-Austerlitz station, consisting of 30 succeeding arches of 10 m. (32 ft. 9 3/4 in.) span, carried on brackets (see photograph, fig. 20) constitutes a system for the stability of which the compensating of the extension of the tie rods, under the effect of the dead load, and of a part of the live load, is essential. This has been obtained by putting the tie rods in tension before concreting them in. In order to obtain this result, they were given a polygonal form that was maintained by connecting the tops of the arches together.—

Other methods of compensation have also been used. We will mention the provisional joints which are suppressed when the permanent load has produced its full effect, and in the case of arches not reinforced, the use of sections cast beforehand, leaving between them a variable proportion of fresh concrete, so as to vary the amount of contraction in a given section as a function of the distance from the neutral axis.

It must be pointed out that without these methods of compensation the increase of the span of arches which appears to be one of the essential features of present day construction work in concrete, as in reinforced concrete, would not have been possible, or at least would only have been possible with stresses under tension which it seems desirable to suppress.

Various causes of deterioration in structures in concrete and in reinforced concrete. Methods of protection.

It is the custom to consider as practically negligible, the maintenance required to preserve structures in concrete, or in reinforced concrete, by likening them to structures in masonry.

It has however been established that under certain circumstances, structures of this kind have deteriorated.

The Swiss Federal Railways have sent us particulars of the observations made during a systematic visit of several bridges in reinforced concrete. These structures showed numerous fissures, mostly due to atmospheric action, the deepest being attributed to the concrete contracting; nearly all these fissures commence in the area of tension of the reinforcement, and diminish with the use of stirrups. It was also found, that rusting of the reinforcement developped especially in parts subject to humidity, to smoke and steam from the locomotives. These visits of inspection also revealed a certain number of defects due to defective construction.

We have received no information with regard to the action of salt water and of electric current on concrete structures.

As regards the action of smoke, from the locomotives, on concrete, Mr. W. W. Grierson, special reporter at the Congress at Rome wrote [1] : « In America, six railways report deterioration, due to this cause; but on the other hand, the experience acquired in Belgium, in France, etc., over a period of six or seven years,

[1] See *Bulletin of the International Railway Congress*, April 1922, page 651.

appears to prove that concrete does not suffer under these conditions. »

As a matter of fact since that time, damage to structures which can be imputed to this cause has been observed. Overbridges and locomotive sheds have particularly suffered. It has moreover been noticed, that the overbridges most seriously damaged, are those near important stations, and especially those under which locomotives stand or move at slow speed.

Under these particular cases, it is necessary to protect concrete structures whether reinforced or not. This question was the subject amongst others of a report presented to the International Congress for the testing of materials held at Amsterdam in 1927. After having reported the effects of the action of fumes: cracking and scaling away of the concrete, rusting of the reinforcements, action on the cement, the reporter studied the origin of these phenomena: physical actions (sudden variations of temperature, difference of temperature between the reinforcement and the concrete) and chemical action on the reinforcement (rusting of the bars) and on the cement (formation of Candlot salt by the action of hydrated lime in the presence of an excess of alumina). The reporter then mentioned the remedies most usually adopted. We give below the principal ones, as well as the protection methods that have been reported by the various Railway Companies.

It is strongly recommended to surround the reinforcements near the facings liable to be affected by a sufficient thickness of material; it appears that the thickness of this coating should be at least 2.50 cm. (1 inch).

It is essential that the concrete should be very compact and that it should show a very smooth surface. In parts of structures particularly exposed to the action of smoke, the use of « ciment fondu » is advisable.

The use of coatings of resisting cement (fondu, siliceous) is very efficacious, on the condition that they are properly united to the structure which requires their application when removing the shuttering.

The use of special paint and protecting coverings, can also be recommended; arch bricks, linings in tiles, wood, of fibrous cement.

It frequently happens in locomotive sheds, that the locomotive chimneys do not come immediately under the lighting up chimneys. In order to prevent disintegration of these structures, it is desirable to lead the smoke through troughs in wood, or in fibrous cement.

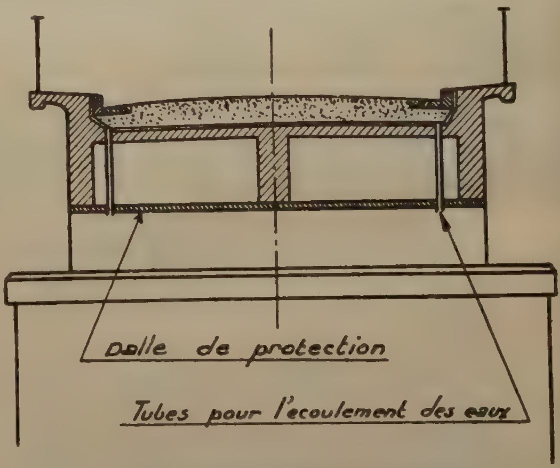


Fig. 21. — Protective arrangement against smoke, for overbridges.

Explanation of French terms ;

Dalle..... = Protection slab.
Tubes pour..... Tubes for drainage of water.

There is an arrangement for protecting overbridges which appears of considerable interest, and which the Paris, Lyons

& Mediterranean Railway proposes to apply systematically to all structures built above its lines near stations. This system consists in securing under the bridge a protecting slab in reinforced concrete, which protects the underside of the bridge from the smoke. The underneath part of the main girders especially, being very difficult to concrete owing to the presence of the large bars at the bottom of the narrow shuttering is also efficiently protected. Openings arranged in the slab make it possible to inspect the passages above it and bounded by it, the floor of the bridge, and the main girders. Owing to the very special care taken in making the slab, it would appear that it should stand up well as regards the action of the smoke; it is furthermore easier to replace it than to repair the structure.

If protective measures have not been taken, it is desirable to repair without delay any structures that may have become damaged. These repairs consists as a rule, in cutting away the disintegrated concrete until sound concrete appears, re-roughing the surface, carefully cleaning it with metal brushes or preferably with a sand jet, washing the concrete and the reinforcement and then recovering the whole by means of strong cement mortar (siliceous, fondu). In order to be sure that the added mortar properly binds to the steel, the Paris, Lyons & Mediterranean Company, have invented the process of electrically welding short pieces of wire 4 mm. (5/32 inch) in diameter to the exposed reinforcements; it would appear that this method is likely to improve the adhesion desired in work of this kind.

As regards the effect of fire upon the concrete, ash pits appear to be the only structures that need be considered.

A covering of hard brick satisfactorily protects the walls of these pits. In the case of double pits, with girders under the rails connected by cross stays and supported by piers, it has been found that the girders and stays when not protected, suffered from the action of the fire, as also the pillars although covered with metal plates. Certain railways consider that the remedy is to use coverings in fire brick.

CONCLUSIONS.

From our enquiry as a whole, it appears that if since the Rome Congress the use of concrete and of reinforced concrete has been largely used on the railways, for building road bridges and even railway bridges of small span, these materials have only been used exceptionnally for railway bridges of medium and long spans. This type of structure appears none the less likely to develop; the use of super cements and of the modern methods of construction that we have noted, cannot fail to facilitate this development.

On the other hand it has been found that many structures in reinforced concrete show more or less serious damage as a result of the action of smoke. Steps should be taken to protect the structures, wherever this action is to be feared, as when damage occurs, the repairs are very difficult, and very costly.

APPENDIX.

Description of bridges in concrete, or in reinforced concrete recently constructed or in course of construction.

a) Bridge over the Nicoba river;
b) Bridge over the Najerilla river;
c) Bridge over the Sambre;
d) Renory viaduct (under construction);
e) Bridge over the Chienti, Tenna, Musone, Potenza rivers;
f) Viaduct over the Great Siva valley;
g) Grandfey viaduct;
h) Bridge over the Marne;
i) Bridge over the Cère;
j) Bridge over the Meuse (under construction);
k) Viaduct over the Elorn (under construction);
l) Bridge over the Usses torrent;
m) Lafayette overbridge in Paris.

a) Bridge over the Nicoba river (Madrid to Saragossa and Alicante Railway).

Situated upon the line from Sevilla to Huelva, this interesting structure is composed of a group of twelve tubes in reinforced concrete, forming, in pairs, independent but contiguous blocks. The inside cross section of the tubes is that of an egg, 3 m. (9 ft. 10 1/2 in.) in height, the length being 9.50 m. (31 ft. 2 in.) the width of the formation for a double track. The independence of the blocks gives the structure a suppleness which preserves it from any damage which a settlement of the ground, which is boggy and unstable, might cause in a rigid structure. Any possible movement of this kind, is transferred to the bed and it is only necessary to relevel the line at a suitable level.

A structure of the same kind has been built on the line between Albacete and Cartagina.

b) Bridge over the Najerilla river (North of Spain Railway).

This structure, situated on the line between Castejon and Bilbao, consists of nine parabolic arches of 30 m. (98 ft. 5 1/8 in.) span in ordinary concrete. The arches have segmental quadrants, and have a thickness of 1.20 m. (3 ft. 11 in.) at the crown, and 1.80 m. (5 ft. 11 in.) at the spring of the arches. The spandrels are lightened by arcaded openings, the soffits of which are profiled in round arches. This bridge is for a double track line.

c) Candelier bridge over the Sambre (Nord-Belge Railway).

This structure carrying the line from Erquelinnes to Charleroi across the Sambre is composed of two straight arched parts, separate, but in plan out of line one with the other, so as to give a skew of about 45 degrees; the span of the arches is 64 m. (209 ft. 11 3/4 in.); each part carries a single track.

In each part, the arch properly speaking is connected to the upper structure carrying the track by side spandrels and an intermediate screen, the whole forming a reinforced unit carried, on the abutments by heavily reinforced concrete joints.

This system of support and the special method of striking the center of the arch

by opening out a crown joint form two particular features of interest of this noteworthy structure. Arrangements were made so that the jacks used when striking the arch could again be used when resetting the structure in case of any movement of the abutments, which has however, never occurred.

Inspection pits in the masonry work of the abutments enable the expansion joints and the pin joints to be inspected.

This structure has been described in an article published in the *Annales des Ponts et Chaussées* (March-April 1923).

d) **Renory viaduct (Belgian National Railway Company), now under construction.**

This viaduct which carries the double track line from Fexhe-le-Haut-Clocher to Kinkempois, consists of nine arches of 61.40 m. (201 ft. 5 3/8 in.) span and one arch of 34 m. (111 ft. 6 3/4 in.). These arches in ordinary concrete are formed by arches with three metal joints.

The spandrels are lightened by arcaded openings in reinforced concrete basket handle shaped so as to harmonise with the soffit curve of the main arches.

The joints are visible and this is the reason why the sections of the arches are spindle shaped.

With the two lines supposed to be carrying a load of 10 tons per linear meter, there was no tensile stress apparent in the arch and the maximum compression load of the concrete is 40 kgr. per cm² (569 lb. per sq. inch).

e) **Railway bridges over the Chienti, Tenna, Musone, Potenza rivers (Italian State Railways).**

The floors of these bridges on the line between Arcona and Pescara, were designed to take a double track line in replacement of steel bridges which owing

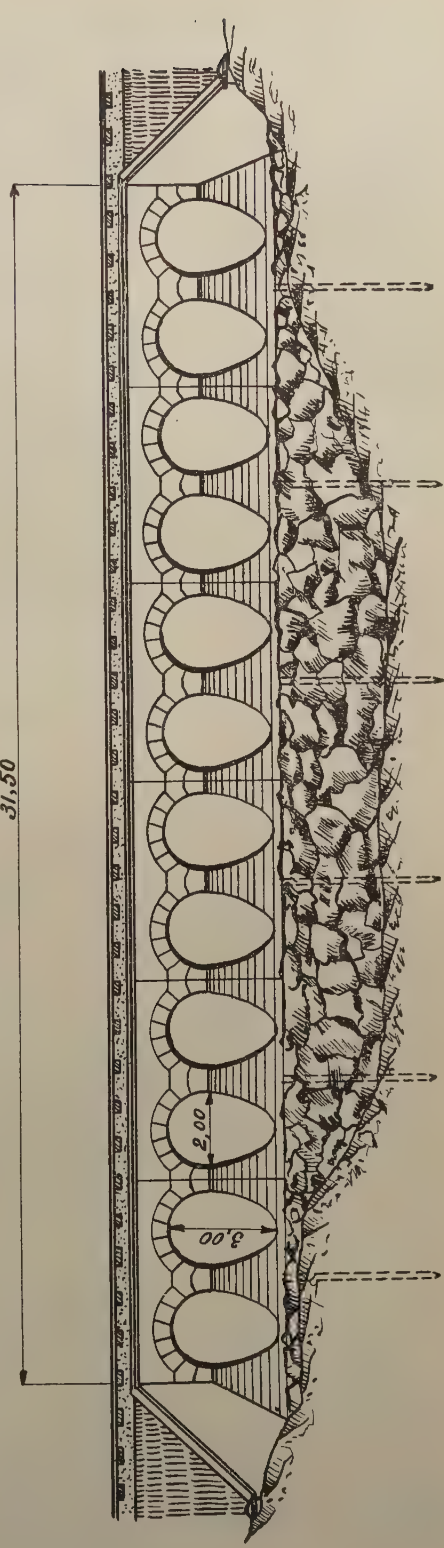


Fig. 22. — Bridge over the Nicoba river.

Fig. 23. — Bridge over the Najerilla. (North of Spain Railway.)

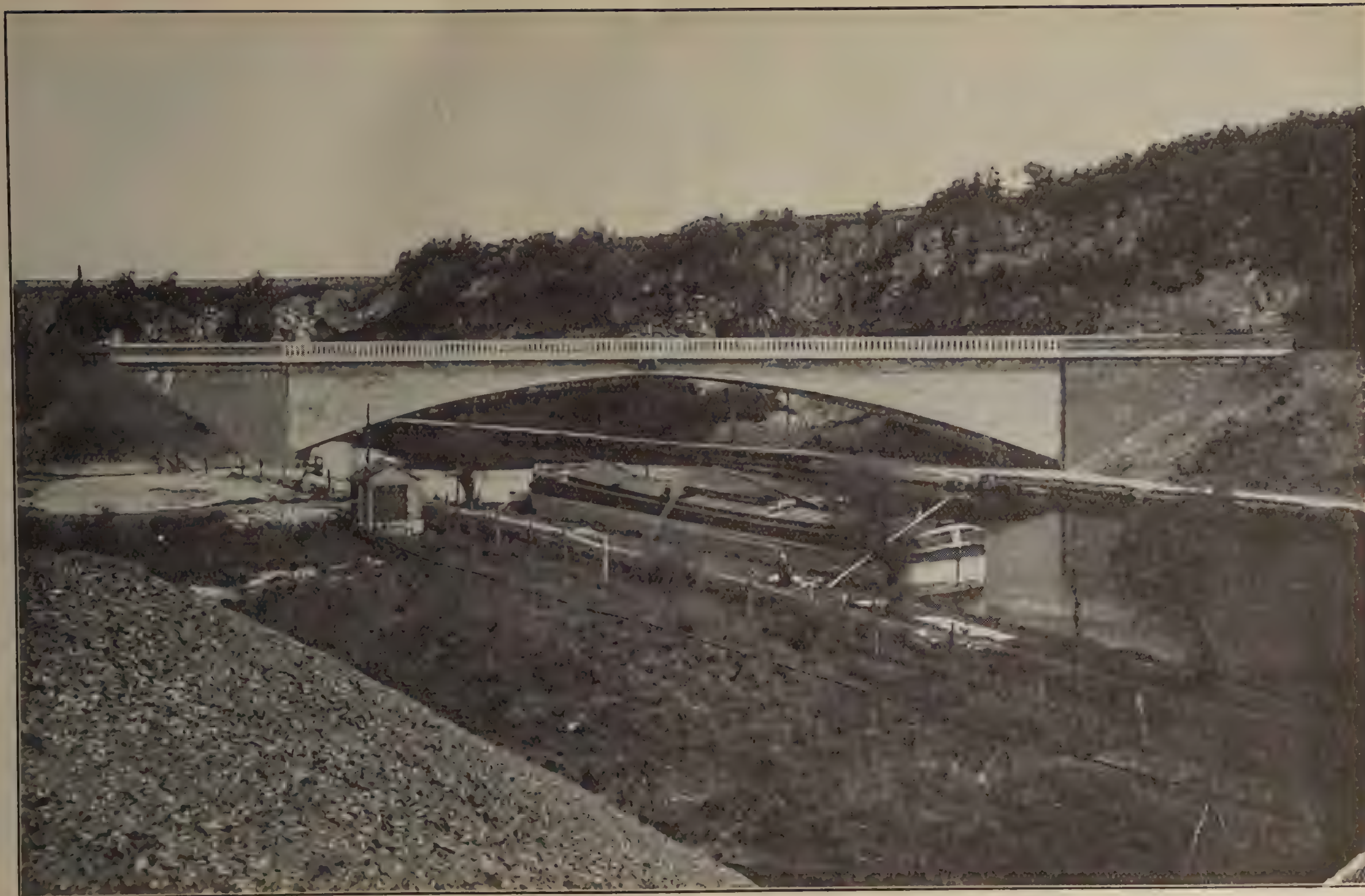


Fig. 24. — Candelier Bridge over the Sambre (Nord-Belge Railway.)

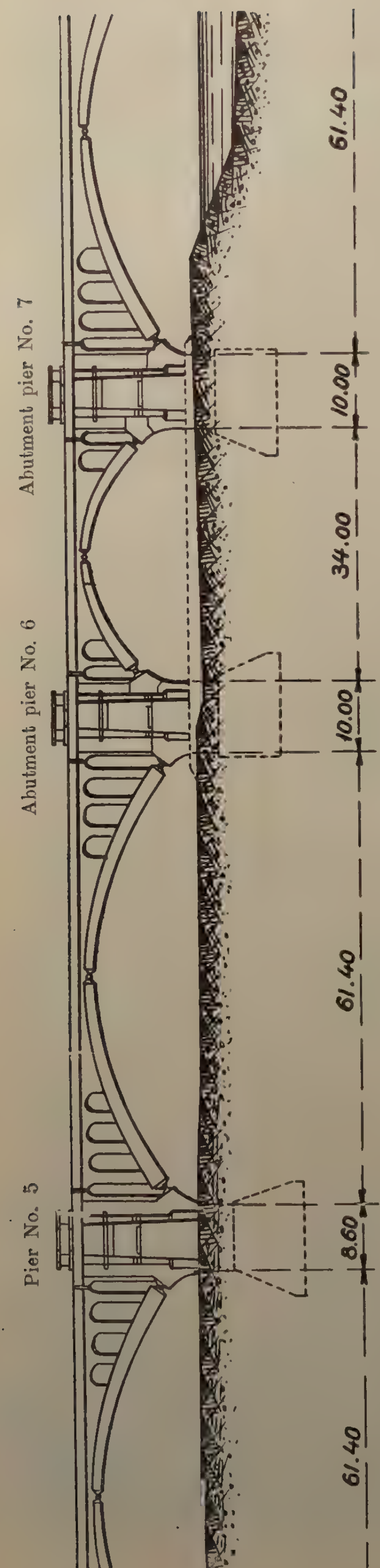


Fig. 25. — Renory Viaduct. Part elevation.

to their insufficient strength prevented the use of heavy locomotives.

The old structures consisted of 3 to 7 bays with spans of 18 to 25 m. (59 ft. 5/8 in. to 82 ft. 1/4 in.). With the object of reducing the span of the new bridges, each span has been divided into two equal parts by the addition of an extra pier; no span so built consequently exceeds 12.40 m. (40 ft. 8 in.). So as not to reduce the waterways through the structures too much, the new piers have been built in reinforced concrete of only 0.50 m. (19 11/16 inches) thickness. The depth of the girders under the rails, is 1.10 m. (3 ft. 7 5/16 in.).

f) Viaduct in concrete, not reinforced, across the Great Siva valley (Italian State Railways).

This structure for a single track consists of 5 circular arches of 20 m. (65 ft. 7 3/8 in.) span.

The thickness of the arches at the crown is 1 m. (3 ft. 3 3/8 in.), and at the abutment 1.20 m. (3 ft. 11 1/4 in.).

The pillars have a thickness of 3 m. (9 ft. 10 1/2 in.) at the spring of the arches.

The maximum height of the structure is 50 m. (164 ft. 1/2 in.).

The spandrels have been lightened by circular openings 2.50 m. (8 ft. 2 7/16 in.) in diameter.

g) Grandfey viaduct (Swiss Federal Railways).

The Swiss Federal Railways have been obliged, in recent years, to replace a large number of steel bridges insufficiently strong to carry their electric locomotives. These works, very difficult to do in the case of important structures, have been carried out with great skill; the construction of the reinforced concrete viaduct of Grandfey near Fribourg, completed in 1925-1926, to carry the

Fig. 26. — Bridge over the Chienti. (Italian State Railways.)

Fig. 27. — Viaduct over the Great Siva Valley. (Italian State Railways.)

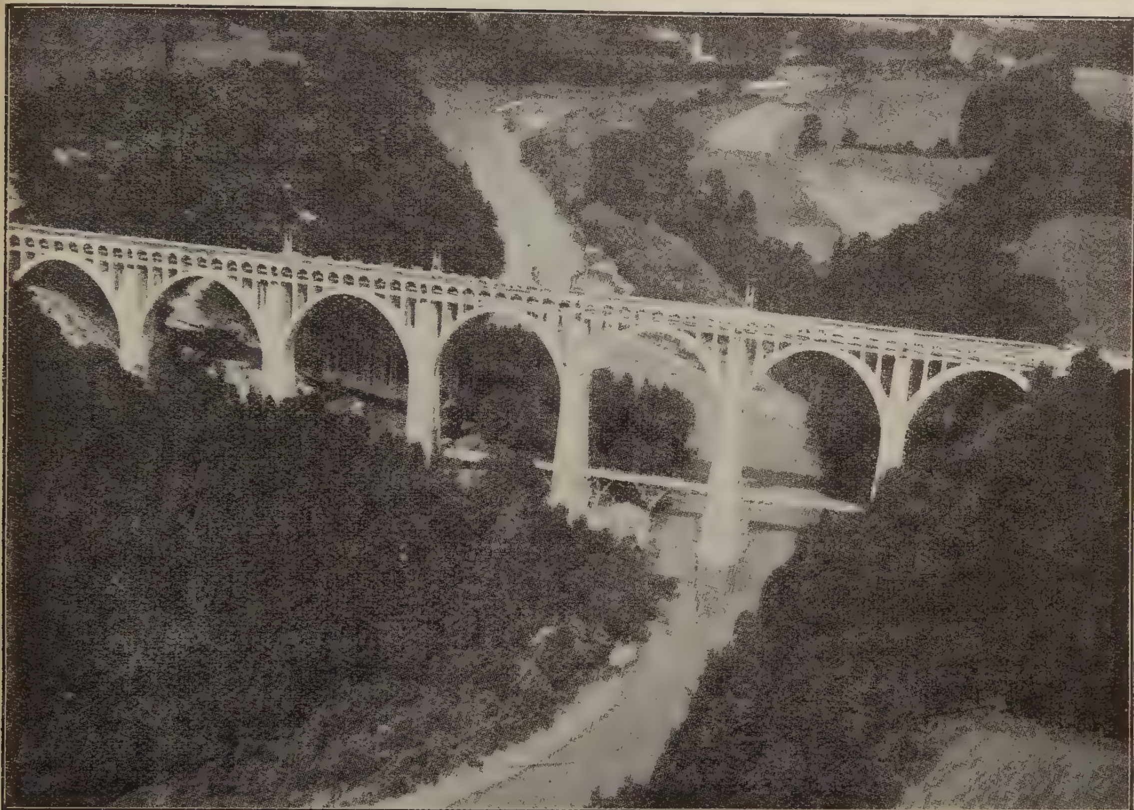


Fig. 28. — Grandfey Viaduct (near Fribourg). (Swiss Federal Railways). — View taken during construction, July 1926.

double track line from Lausanne to Berne, is undoubtedly the most remarkable of these structures.

The former structure consisted of 7 steel spans of 42 to 49 m. (137 ft. 9 1/2 in. to 160 ft. 9 1/4 in.) opening. The steel piers have been connected together by arches in reinforced concrete the reinforcement serving as shuttering.

The load on the new flooring forming a trough for the ballast has been transferred on to these arches by small arches in reinforced concrete.

The photograph (fig. 28) shows that the appearance of the structure thus obtained is very pleasing and harmonises well with its surroundings.

h) Neuilly-sur-Marne bridge (Paris Girdle Railway).

Built for two lines of railway this structure entirely in reinforced concrete, on the line from Bobigny to Sucy-Bonneuil, consists of a main arch of 67.50 m. (221 ft. 5 1/16 in.) span, with three joints, formed of two booms connected together by five vertical ribs. The lower boom is profiled to a slightly ogival curve; the upper boom, rectangular and the middle part of the structure, has the form of a cubic parabola in the other parts. The exterior ribs are extended above the upper boom by light walls of concrete forming the spandrels.

Fig. 29. — Bridge at Neuilly-sur-Marne.
(Paris Girdle Railway.)

The joints are in stirruped concrete.

A footbridge is provided alongside the structure; it is formed by a solid flooring running alongside the soffit.

This arrangement avoids the use of unsightly steps, and facilitates the circulation of the public.

i) Laval-de-Cère bridge (on a branch line connected to the Orleans Railway).

This structure, built for standard gauge lines, is entirely in reinforced con-

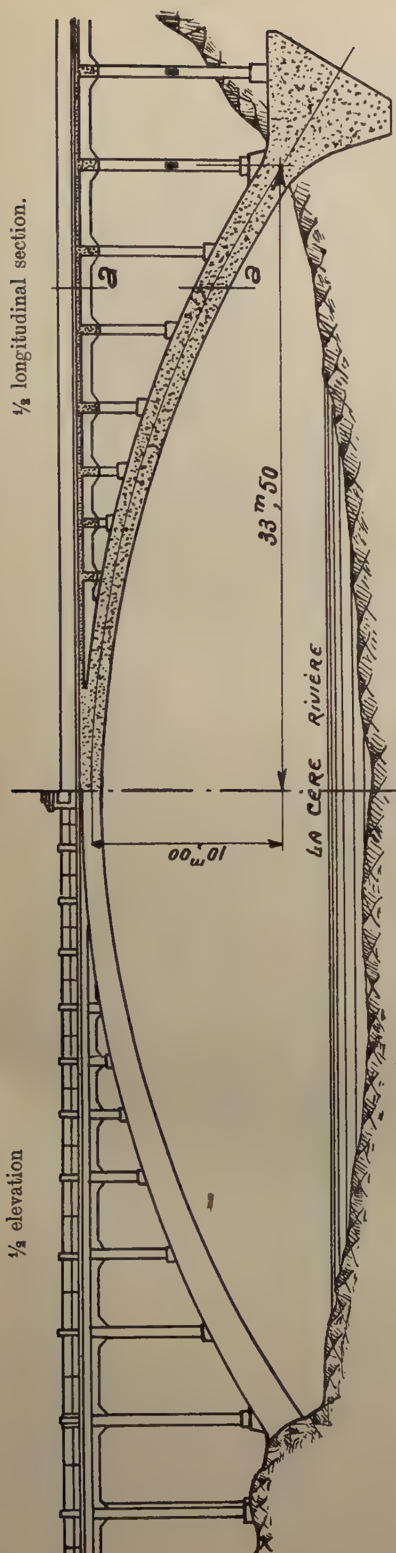


Fig. 30. — Bridge over the Cère river.

Section on aa.

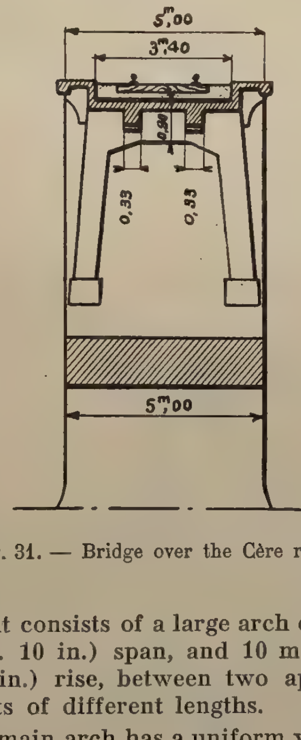


Fig. 31. — Bridge over the Cère river.

crete; it consists of a large arch of 67 m. (219 ft. 10 in.) span, and 10 m. (32 ft. 9 3/4 in.) rise, between two approach viaducts of different lengths.

The main arch has a uniform width of 5 m. (16 ft. 5 in.) and a thickness varying between 0.80 m. (2 ft. 7 1/2 in.) at the crown, and 1.40 m. (4 ft. 7 in.) at the spring of the arch. It is keyed into abutments in concrete each having a

base area of about 50 m² (861 sq. feet). The flooring is carried by means of twin pillars spaced 4 m. (13 ft. 1 1/2 in.) apart.

The arch was made in concrete with super cement. The reinforcements autogeneously welded together are continuous.

The approach viaducts rest on piers placed 6 m. (19 ft. 8 1/4 in.) apart, and formed of two cross braced columns.

The flooring is of uniform thickness; it is formed with a central trough carrying the ballasted track with two footpaths carried on cantilever brackets.

j) Boncourt bridge over the Meuse (French Est Railway), now under construction.

Built to carry two tracks, this structure on the Lérouville-Metz line, is laid on a curve of 600 m. (30 chains) radius. The spandrels are rectilinear.

The bridge is constructed throughout in concrete, including the facing and the parapet.

The arch in stirruped concrete, has a span of 42 m. (137 ft. 9 1/2 in.); the rise of the arch is 1/7.64.

The neutral axis is a parabola of the 4th degree; at the crown, the radius of curvature is 41 m. (134 ft. 6 1/4 in.).

The working stress in the concrete does not exceed 45 kgr. per cm² (640 lb. per square inch).

The coping of the spandrels is in concrete strongly reinforced; it forms a strongly marked corniche along the face of the structure, and is higher than the top of the ballast so as to act as a protection in the event of derailment on the bridge.

The centering and the loading of the arch were carried out by opening, with the help of hydraulic jacks, a joint arranged at the crown.

k) Plougastel viaduct on the Elorn estuary near Brest (under construction).

This viaduct will consist of three arches in reinforced concrete carrying a double platform, the upper forming a roadway, the lower carrying a standard railway line.

The total length of the structure including the approach viaducts, will exceed 800 m. (2 625 feet).

The three arches have a span of about 180 m. (590 feet) and a rise of 33 m. (108 ft. 3 1/4 in.); the neutral axis is a funicular of the permanent loads that the arches will carry.

Each arch is formed of two parallel tubular arches of rectangular section, each formed by two blocks acting as tables, and two as spandrels. The space between these two arches is a little greater than the cross section of the track. The arches are connected by two blocks extending the tables. The arch has a uniform length of 9.50 m. (31 ft. 2 in.) and a height varying between 4.30 m. (14 ft. 1 5/16 in.) at the crown and 9 m. (29 ft. 6 3/8 in.) at the springing.

The double platform is formed by the two lattice girders connected together below by the concrete block carrying the railway line; at the top by the concrete block carrying the 6-m. (19 ft.-8 1/4 in.) roadway, and the two 1 m. (3 ft.-3 3/8 in.) wide foot paths. At the crown the width of the top platform is increased to 9.30 m. (30 ft. 6 in).

The platform is carried on the arch by means of supports in the form of two piers connected by a screen wall.

The abutments are formed by simply enlarging the arches, the tables of which increase in thickness very quickly until they reach the full section.

The three arches are moulded one after the other by a succession of rollers with the help of a single centering.

The impossibility of carrying the centering upon intermediate supports made

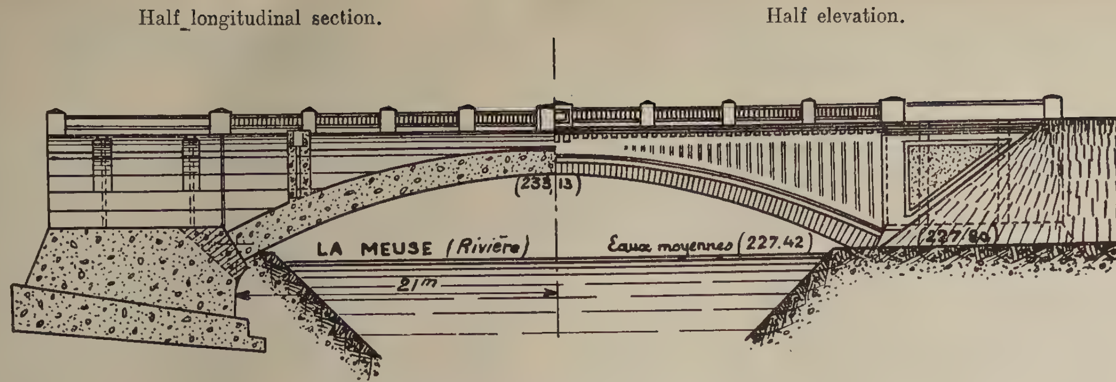


Fig. 32. — Bridge over the Meuse.
Explanation of French terms : Eaux moyennes = Mean water.

Fig. 33. — Plougastel Viaduct of reinforced concrete.

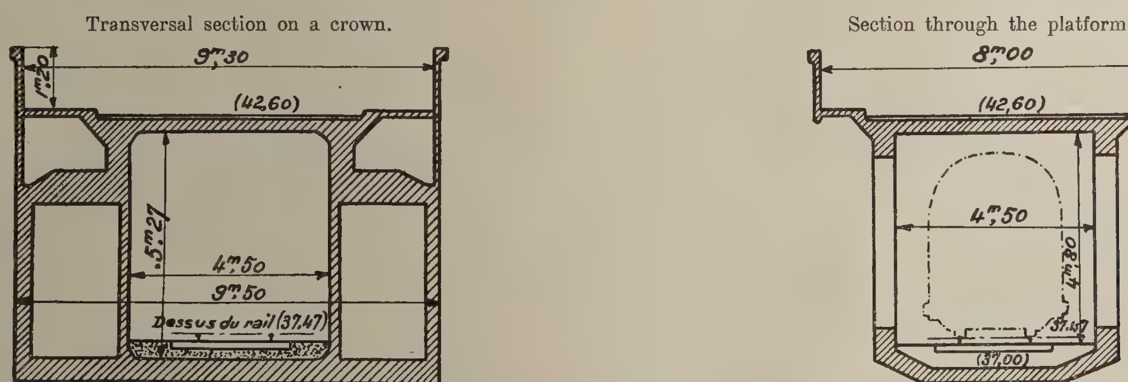


Fig. 34. — Plougastel Viaduct of reinforced concrete.
Explanation of French terms : Dessus du rail = Top of rail.

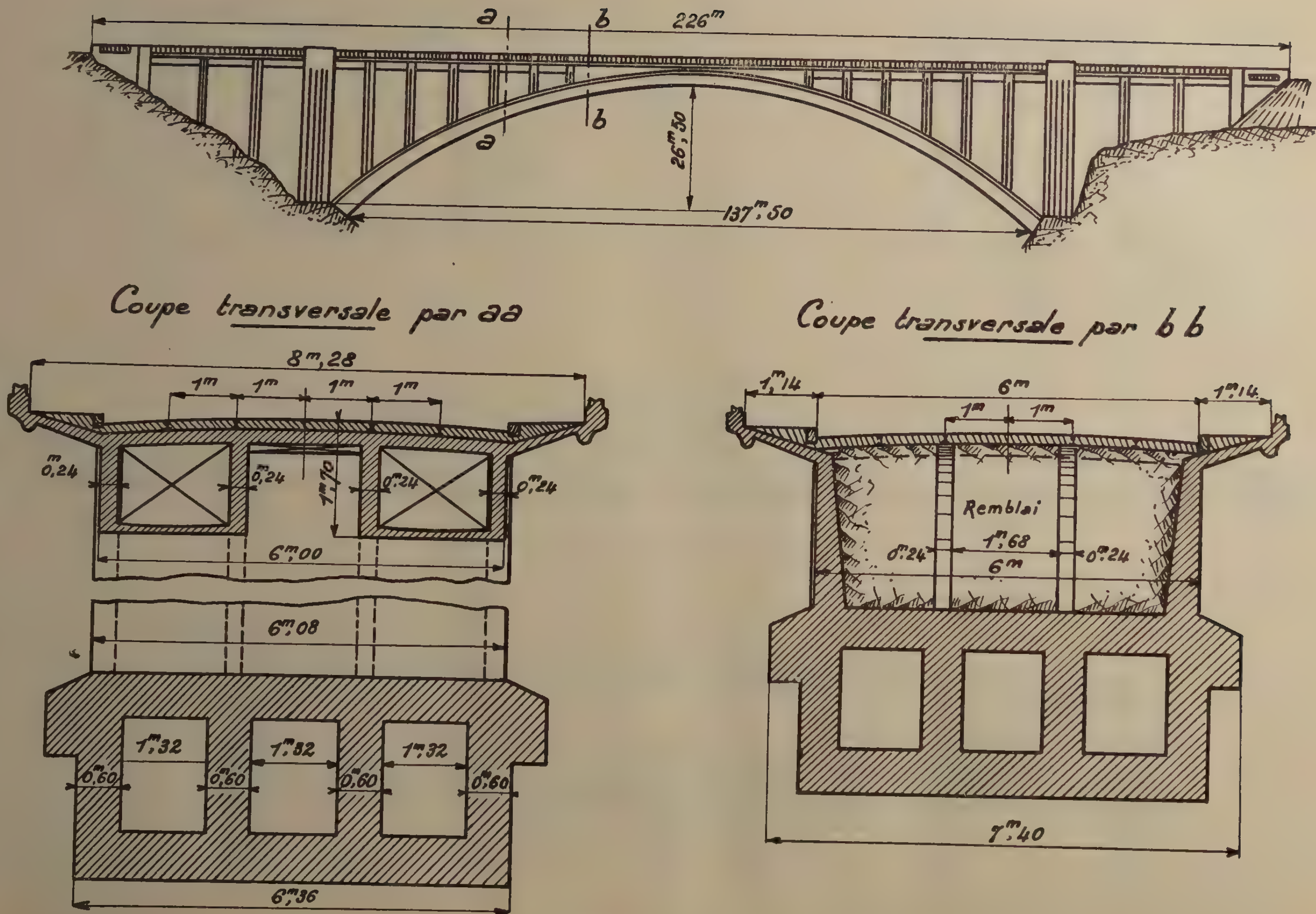


Fig. 35 — La Caille concrete bridge.
Explanation of French terms : Coupe transversale par..... = Transversal section through....,.

Fig. 36. — Lafayette overbridge at Paris. — Removing the shuttering of a main girder.
(French Est Railway.)

it necessary to use a centre turned up and carried on pontoons when moving it from one arch to the other.

l) Caille bridge over the Usses torrent (Haute-Savoie).

This bridge, which has the unusual span of 137.50 m. (353 feet) was built to take a road and a double line of metre gauge railway.

The main arch built in at the abutments, is in concrete, but not reinforced; its theoretical span is 140 m. (459 ft. 3 3/4 in.), its thickness is 2.80 m. (9 ft. 2 1/4 in.) at the crown, and 4.58 m. (15 ft. 11/32 in.) at the spring of the arch. It has three openings, and appears in the form of two arches superimposed one upon the other connected by four vertical screen walls 0.60 m. (23 5/8 inches) thick. It was run in three rollers corresponding to the lower boom, to the vertical ribs, and to the upper boom, so as to keep the turned up shuttering within permissible dimensions. In each roller the construction was carried out by means of quoins approximately a third of the volume being formed by quoins 0.18 m. (7 3/32 inches) thick prepared beforehand, and the remainder cast in place.

The distribution of the quoins in each roller was calculated in such a manner that the difference of shrinkage due to the difference in proportion of new concrete, would produce rotary movements compensating those which would occur in a homogeneous arch, under the influence of the shortening of the neutral axis.

The platform in reinforced concrete rests on the arch through a fill in the centre part and on five piers in reinforced concrete on both sides thereof.

This structure was built on wood centering formed of four sets of arch shaped trusses of the same span as the arch itself, firmly braced together, and stayed by outside cables anchored in the rock.

The centering was erected by means of a suspension bridge, the platform of which has the shape of the soffit of the centering, calculated and designed to carry the two outsides trusses.

These trusses were then used for the two intermediate ones. To reduce the effect due to the shortening of the neutral axis, provision was made in the upper bearings for a joint 11 mm. (7/16 inch) wide at the crown, which is only closed when the lower bearings are under sufficient compression.

The ends of the trusses rest on boxes, filled with sand, made in reinforced concrete.

m) Lafayette overbridge in Paris (French Est Railway).

Consisting of two sensibly equal spans, over the lines leading into the gare de l'Est, this structure entirely in reinforced concrete has a length of 137 m. (451 feet) and the unusual width of 20.40 m. (66 ft. 11 in.).

The two main girders in triple trellis work have a depth of 10.40 m. (34 ft. 1 1/2 in.) throughout. The stringers and the struts are also trellis girders; their depth varies from 2 to 3 m. (6 ft. 6 3/4 in. to 9 ft. 10 1/8 in.).

The structure has two platforms, one carrying the road and the footpaths and the other protecting the bridge against the action of smoke.

The expansion rollers are in stirruped concrete.

Cement and steel of high strength were used in the construction of this bridge.

SUPPLEMENT.

In our report upon the use of concrete and reinforced concrete on railways, we did not mention the use of reinforced concrete for strengthening existing metal structures.

The present supplement to our report has as its object the making good of this omission by reporting the work of reinforcement of viaducts in cast iron carried out in France by the Paris, Lyons & Mediterranean Railway Company.

The first work of this kind was carried out in 1923, on the viaduct over the Rhône at La Voulte. This structure consists of five arches in cast iron of 55.60 m. (182 ft. 4 3/4 in.) span.

The reinforcement included amongst other operations :

1. The fastening of the reinforcements to the weak parts of the arches and the covering of these reinforcements with concrete;

2. The construction of reinforced concrete flooring to bind the arches together one with the other, at the level of the soffit and under the track;

3. The thickening up of the spandrels in the transverse direction.

Before reinforcement, the cast iron arches under a load of 6 000 kgr. per linear meter (3 628 lb. per linear foot) of the track, revealed stresses exceeding the allowed limits by 59 % at the spring of the arches, and by 68 % at the crown.

After reinforcement, an experimental test showed that under the load of the *Pacific* locomotives (7 000 kgr. per linear metre [4 233 lb. per linear foot] of track), the actual stresses in the arches did not reach at any point the limits allowed in the regulations.

Tests to measure the actual stress, under the action of a light engine weighing 4 500 kgr. per linear metre (2 721 lb. per linear foot), of the track, were also made before and after the reinforcement of the structure.

The table below shows the value of the results obtained :

—	Actual average stress under live load, in kgr. per mm² (in English tons per square inch).	
	Prior to reinforcement.	After reinforcement.
Crown :		
Extrados . .	+ 2.24 (+ 1.42)	+ 0.49 (+ 0.31)
Intrados . .	— 1.04 (— 0.66)	— 0.23 (— 0.14)
Haunches :		
Extrados . .	+ 0.38 (+ 0.24)	+ 0.24 (+ 0.15)
Intrados . .	+ 1.34 (+ 0.85)	+ 0.16 (+ 0.10)
Springing :		
Extrados . .	— 1.22 (— 0.77)	— 0.91 (— 0.58)
Intrados . .	+ 3.04 (+ 1.93)	+ 0.88 (+ 0.56)

The replacement of the cast iron arches considered in 1913 would have cost, had it been carried out in 1923, about 5 million francs; the strengthening by means of reinforced concrete has cost less than 2 millions.

These works are described in an article by Mr. de Boulongne, Chief Engineer for steel construction of the Paris, Lyons & Mediterranean Railway, which appeared in the *Annales des Ponts et Chaussées* (September-October, 1924).

Similar reinforcement work has been carried out on the viaducts over the Rhône at Chasse (*Annales des Ponts et Chaussées*, May-June, 1926), at Lyons and to the viaduct over the Isère, at Montmélian. The reinforcement of the viaduct over the Rhône at Saint-Rambert d'Albon will be carried out very shortly.

[625. 143]

REPORT No. 2

(all countries except America, the British Empire, China and Japan)

ON THE QUESTION OF THE RESISTANCE OF RAILS AGAINST BREAKAGE AND TO WEAR (SUBJECT II FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By Mr. CAMBOURNAC,

ENGINEER, BRIDGES AND ROADS SERVICE,
ASSISTANT CHIEF ENGINEER FOR WORKS AND SUPERVISION OF THE FRENCH NORD RAILWAY,

and

Mr. PATTE,

CHIEF ENGINEER ATTACHED TO HEADQUARTERS OF THE PERMANENT WAY AND WORKS DEPARTMENT OF THE FRENCH EST RAILWAY.

Figs. 1 to 55, pp. 2021 to 2109.

Question II (Track): the questionnaire on this subject was distributed by the headquarters office of the Association to 140 Railways in April 1928.

60 Railway Companies have sent in replies which are analysed below and are followed by the observations of the reporters.

A. — RAIL BREAKAGES.

§ 1. — *The statistical information relating to the breakages of rails has been published in the* « Bulletin of the International Railway Congress Association » *(December 1926, October 1927, November 1928).*

Have you drawn any conclusions from these statistics, and if so, what are they?

Do you think any modification should be made in the way the tables are arranged, especially as regards the classifcation of the fractures by their appearance as recommended by the London Congress of 1925 (Final Summary No. II) ?

The different companies consider the statistics of broken rails should be supplied in the way agreed upon at the Lon-

(1) This question runs as follows : « Resistance of rails against breakage and to wear.

« *A*) First causes of rail breakage ; measures taken to reduce the number of breakages, both as regards the way rails are used and the conditions of inspection.

« *B*) Quality of metal used for rails to give normal wear. Conditions governing manufacture and inspection.

« Rails : profile and quality, length, weight, and cross section of the rails.

« *C*) Rail joints. The most economical and efficient design. »

(2) Translated from the French.

don Congress in 1925, subject to the slight modifications given below :

The French State Railways are of opinion that the breakages should be classified, not only by their appearance, but in addition, by the probable causes to which they are due.

The French Est Railway suggests the extension of the tables :

a) by carrying rather further the division in 5 yearly periods;

b) in relating the number of breakages not only to the train-kilometres which does not bring in either speed or tonnage, but to the tonne-kilometre and by giving an indication as to the speed;

c) by simplifying the classification of the fractures according to their appearance.

The Midi Railway (France) would like the statistics to show the number of rails broken by surface fissuration of the head of the rail.

The Paris to Orleans Railway suggest that the position of the rail in the track (on the straight, curve of..., radius, inner rail [lower] or outer [higher]) should be stated.

The Paris, Lyons & Mediterranean Railway propose that breakages occurring on underground lines should be classified separately.

The Gafsa Railway (Tunis) suggest that the position of the fracture when outside the joint should be given in relation to the two ends of the rails and to the sleepers on each side of it.

The Italian State Railways consider that it would be useful to show the breakages separately, according as they occur in tunnels or in the open, in line with holes or in the solid.

The Rumanian State Railways suggest :

a) to complete the statistics by giving the number of tonne-kilometres and by the total length of the system;

b) to reduce from 42.5 kgr. to 40 kgr. (85 to 80 lb. per yard) the line between medium and heavy weight rails.

The Swiss Federal Railways propose that the % of fractures with oval stain be not introduced, and that the number of pieces into which the rail breaks, be not given.

The Rhætian Railways (Switzerland), would like the statistical tables to indicate the cause of failure.

We find that most of the railways, whilst unable to state precisely the conclusions they have drawn from the annual publication, moreover of recent date, of the statistical information as decided at the London Congress in 1925, are of the opinion that it should be continued.

The value of such publication no longer requires demonstration : each company has undoubtedly compared its own statistics with those of the companies on which the conditions of the line, or of the traffic are most like its own.

Nevetheless, it would appear of value if the present statistics were extended and modified in the method of presentation as indicated below.

1. — Two distinct tables should be drawn up, one for rails above ground, and the other for those underground : a third table would give the results as a whole.

2. — Not only the number of train-kilometres, but also the number of tonne-kilometres, should be given, in order to remove the lack of information as to the weight of the train.

This number of tonne-kilometres, could be obtained from the total.

a) of tonne-kilometres, of ordinary goods traffic;

b) of tonne-kilometres of fast goods traffic;

c) of tonne-kilometres representing the passenger traffic : this figure being obtained by multiplying by 0.1 tonne (conventional weight allowed per passenger and luggage) the number of passenger-kilometres carried annually.

3. — The percentage of rails broken should be shown divided as between those broken on straight sections, and on curves, and in this latter case, whether as the inner (or lower) rail, or on the outer (or higher).

4. — Owing to the mistakes in judgment committed by the outside staff in the sections, it would appear advisable to suppress in the case of broken rails with a sharp clean fracture, the distinction between rails with and without oval stain: the oval stain is, moreover rare on European railways.

5. — In order to bring out fractures due to surface fissuration of the rail head under the action of passing trains, notably in case of slipping or braking, steps should be taken as regards fractures, partly old and much oxidised extending to the outer surface of the rail head to classify them according as the said surface reveals superficial fissurations or not.

These considerations being taken into account, the tables now in use, should be replaced by those given below.

§ 2. — *What steps have been taken, either on your own account, or in collaboration with the Steel Makers to investigate the initial causes of broken rails?*

What results have been obtained from the investigation ?

Have you in particular arrived at any results as regards :

a) *silver oval stain;*

b) *superficial fissuration of the running surface of the rails through the action of passing trains.*

The Belgian National Railway Company investigated at the Malines works all interesting fractures, subjecting the broken rails to various mechanical, chemical and metallographical tests.

Several cases of oval stains and of superficial fissuration have been found.

Several such oval stains are as a rule found in the same rail. The metal of these rails was found to be fairly hard ($C > 0.5$; $Mn > 1.00$).

Superficial fissurations have been observed at places where engines slip, or where the brakes are used frequently.

The Company considers that to avoid the danger resulting from these fissurations, it is desirable to use for rails a steel that is not brittle.

The majority of the main French railways carry out in their laboratories systematic investigations into rails broken or damaged which appear to have some feature of interest, and especially in the case of rails supplied in accordance with standard specifications of July 1923.

They have in addition referred to a committee composed of three railway engineers, and three metallurgists, the question of reporting on the improvements that should be introduced in the manufacture, and in the inspection of rails.

The Paris, Lyons & Mediterranean Railway has not been able to arrive at any certain results from the examination of rails, the fracture of which shows the oval stain, which rails are moreover rare.

RAILWAY COMPANIES AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.		
	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).
1	2	3	4	5	6	7	8	9	10
. . . . Railway.									
							A. — **Rails nc**		
Light rails : weighing less than 42.5 kgr. per m. (85 lb. per yard).									
Medium rails : weighing between 42.5 and 52.5 kgr. per m. (85 and 105 lb. per yard).									
Heavy rails : weighing 52.5 kgr. per m. (105 lb. per yard) or more.									
Total . . .									
								B. — **Rai**	
Light rails : weighing less than 42.5 kgr. per m. (85 lb. per yard).									
Medium rails : weighing between 42.5 and 52.5 kgr. per m. (85 and 105 lb. per yard).									

ails.								
15 to 20 years.		Over 20 years.			The whole of the rails.			
Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track.	Number of breakages per 1000 km. (625 miles).	Maximum axle weight.
12	13	14	15	16	17	18	19	20
tunnel.								
unnel.								

RAILWAY COMPANIES AND DESCRIPTION OF RAILS.	Ag								
	Less than 5 years.			5 to 10 years.			10 to 15 years.		
	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).
1	2	3	4	5	6	7	8	9	10
									B. — **Rails**
Heavy rails : weighing 52.5 kgr. per m. (105 lb. per yard) or more.									
Total . . .									
									C. — **Tot**
Light rails : weighing less than 42.5 kgr. per m. (85 lb. per yard).									
Medium rails : weighing between 42.5 and 52.5 kgr. per m. (85 and 105 lb. per yard).									
Heavy rails : weighing 52.5 kgr. per m. (105 lb. per yard) or more.									
Total . . .									

Number of { train-kilometres . / train-miles . . . . } . . . .

Number of { tonne-kilometres . / ton-miles . . . . . } . . . .

… rails.										
	15 to 20 years.		Over de 20 years.			The whole of the rails.			Maximum axle weight.
Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track of this class.	Number of breakages per 1000 km. (625 miles).	Number of breakages.	Length of single track.	Number of breakages per 1000 km. (625 miles).	
11	12	13	14	15	16	17	18	19	20

…unnel. (*Continued.*)

…r *A* and *B*.

Number of breakages:
- Total . . . .
- per 10 000 000 train-kilometres . . / per 6 250 000 train-miles. . . . . . ……..
- per 1 000 000 000 tonne-kilometres. / per 612 000 000 ton-miles . . . . . ……..

	Percentage of breakages		Percentage of breakages		
	in the fish plates.	outside the joint.	on straight lines.	on curves	
				lower rail.	higher rail.
D. Light rails.					
D. Medium rails.					
D. Heavy rails.					

	Light rails.	Medium rails.	Heavy rails.
E. — *a*) **Sharp clean fracture**			
b) **Fracture partly old, much rusted, reaching to the outside surface of the foot, or of the head of the rail** — in the foot			
b) — in the head — with surface fissurations			
b) — in the head — without surface fissurations			
c) **Fracture including an old part much rusted which does not reach to the outside surface of the foot or of the head of the rail** — in the web			

It is of opinion, however, that the stain may be present without there having been any preexisting cavity in the rail.

As regards superficial fissuration, the French Midi Railway has observed it in rails without any trace of slipping, nor any surface hardening, and thinks it can occur at places other than those at which the locomotives are liable to slip.

The Gafsa Railway (Tunis) from an examination of the broken rails found either visible defects in the metal, or segregation which was revealed by macrography.

The Italian State Railways attribute a large number of the breakages and damage cases investigated to piping and segregation, and are endeavouring to remove these defects by rigidly applying the specifications and by closer control during manufacture. They have taken in hand an investigation into the first cause of the defect known as « oval stain » which was only very rarely found in rails of more than 40 years of age, but so far without obtaining any result. They have on the other hand, found that the superficial fissuration of the rail head is due either to work hardening, or to temper hardening through slipping.

The Netherlands State Railway Company and the Dutch Railway Company have systematically examined for some time all broken rails, but so far, without result.

The Rumanian State Railways carry out twice yearly, in the spring and in the autumn, by a Committee of its Engineers and Engineers from the Works concerned, an examination of the rails in service. The Works which are enabled in this way to see how the rails behave in service, have been able to improve their manufacturing methods and recent supplies of rails show an improvement.

The oval stain is a very rare defect. No observation is made on superficial fissuration.

The Swedish State Railways are carrying out mechanical, chemical, and metallographical tests on the broken rails.

The result of these tests is to show that the breakages are due to segregation in the metal, to flat spots on the tyres, and to unfavourable temperature conditions (severe cold or sudden changes).

The Swiss Federal Railways arrange with the Federal Materials Testing Laboratory at Zurich, for each broken rail, the fracture of which has some particular feature of interest, to carry out tests to ascertain the cause of breakage.

In most of the cases investigated in 1926-1927, the laboratory found $C > 0.45$, $S > 0.05$, $Ph > 0.10$, which appears to indicate a somewhat brittle material. As a result of these investigations this Railway specified, at the end of 1927, $C < 0.45$, $S < 0.05$, $Ph < 0.08$ and $Si < 0.15$ with at the same time $Mn > 1.05$.

We find that most of the Railways have in conformity with the wish expressed at the London Congress of 1925, developed their means of enquiry and investigation with a view to ascertaining the causes of rail breakage.

We consider there is every advantage to be gained by multiplying and extending this research work in collaboration with the Steel Makers in the way that has been followed by the French Railways and the Rumanian State Railways.

We think in this connection, that some details should be given of the work of the joint Committee which functions in France.

This Committee examines the cases of fracture and damage submitted to it by the railways (over 150 up to the present date) and most of which relate to rails manufactured according to the 1923 Specifications.

The principal defects revealed by this examination, are as follows :

1. Rails having inclusions of steel other than that of the cast.

Such inclusions are found when the Works try to protect the base plates of the ingot moulds against the stream of metal, by pieces of plate or scrap iron. The plate or piece of scrap rising in the liquid metal, contaminate the ingot generally in the lower part.

Rails made from such contaminated ingots split and show in particular breaking away of the head (fig. 1).

This defect is revealed by macrography (figs. 3 and 4).

The macrograph shows, according to the case, either an inclusion with well defined edges (fig. 5) or with edges not clearly marked (fig. 6).

2. Rails showing longitudinal splits in the foot.

It has been found that some rails breaking with a straight transversal fracture, (most often above a sleeper) show under the foot, a longitudinal split following for a certain length the direction of rolling (figs. 7 and 8).

The examination by the naked eye and the macrographical study (figs. 9 and 10) of these splits, show that they are made up of two quite distinct parts :

The one, at right angles to the foot of the rail and with the sides of the split covered with foreign matter (oxidised metal and slag). In this part the edges of the split show longitudinally, a characteristic ligneous appearance (fig. 11); this part of the split, consequently, dates from the rolling.

The other, which follows after the first, develops across the ferrite polygons and its walls are free from foreign matter : it is a split through the solid metal which had its first beginning at the end of the first part through the stresses to which the foot of the rail has been subjected after rolling, either during manufacture (cooling, cold straightening) or in service in the track.

It has been recognized that such longitudinal splits can exist in the rail, both in the head, and in the foot without appearing on the surface, so that they are impossible to see either by the naked eye or with a magnifying glass.

These splits start in the cracks which are produced in the blooming mill, by too quick rolling under excessive pressure on the ingot, when the ingot is too hot, or when its chemical composition makes it specially liable to develop cracks.

It has been found possible to reproduce such splits as described, by repeating the conditions. It has been observed, in addition, that these splits do not open on the outside when the rails are straightened with care in a press : straightening them by rolling, on the contrary, causes them to open, at least in cases when the split is already rather large.

These splits also open in the foot of the short length subjected to the drop test which therefore provided a means of revealing their presence.

3. Rails showing superficial rolling defects (flaking, cold shot, etc.).

Defects of these kinds are investigated by micrography which shows for the parts rewelded during rolling, a charac-

Fig. 1. — Breaking away of the head of a rail as a result of the presence of foreign matter extraneous to the cast.

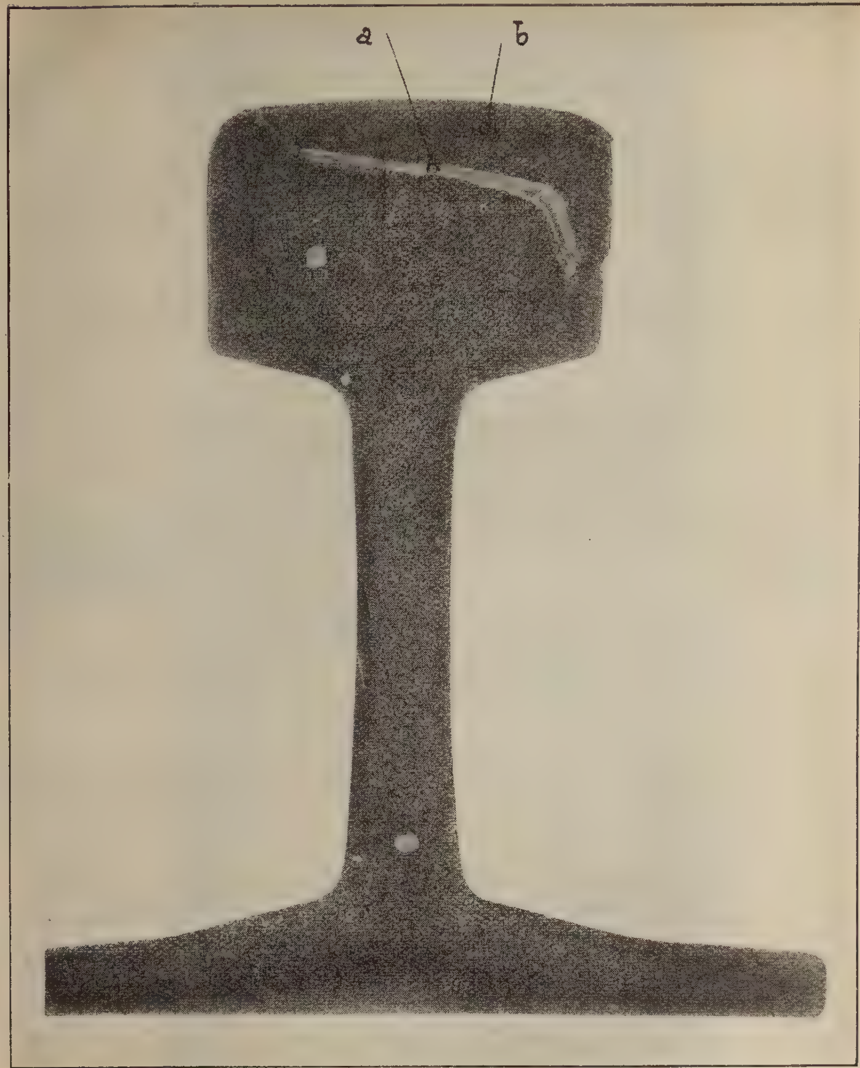


Fig. 2. — Macrograph of a section of the rail shown in figure 1.

Fig. 3. — Micrograph at point *a* of figure 2 (enlargement 83 D).

Fig. 4. — Micrograph at point *b* of figure 2 (enlargement 83 D).

teristic aspect after etching the surface (fig. 12).

4. Rails showing piping and segregation.

These rails reveal splits in the web and in the head, especially when the end of the rail which corresponds to the head of the ingot comes, on the side of a joint on which the wheels run on to the rail.

The examination of these rails has revealed extremely varied forms of segregation according to the condition under which the ingots were poured and solidified.

In quite a large number of cases the outer edges of the section of the rail appears on the macrograph with a much lighter colour than the remainder of the section. This clear zone may be one or several millimetres in width (figs. 13 and 14).

The examination (micrography, chemical analysis) of this zone, shows that it is not only freer from sulphur, but also that the carbon content is lower than in the body of the section.

It appears moreover that this result should not be ascribed to oxidation produced by the ingot remaining too long in the pits, in an oxidising atmosphere; such oxidation could only be superficial (a few tenths of a millimetre in depth at most) and the explanation ought to be looked for in the liquation which accompanies the solidification of the ingot.

This zone of metal at the edges, is most often separated from the bulk of the section by impurities which show themselves on the macrograph by black points on the line between the two zones (fig. 14). These impurities are brought out with great clearness by etching tests (fig. 15).

Fig. 5. — Macrograph showing an inclusion (piece of rail) with well marked edges.

The micrographical study of these black points made after etching on a section taken at right angles to the direction of rolling does not readily reveal the presence of impurities : in line with the black points a polygonal appearance of ferrite in every way comparable with the aspect of the run of the section is found.

But, against this, the same investigation carried out after etching a section taken parallel to the direction of rolling reveals cavities (blow holes) lengthened out in the direction of rolling and containing slag.

In other cases, on the other hand, the edge of the section showed on the macro-

Fig. 6. — Macrograph showing an inclusion with indistinct edges.

graphs a darker shade than the centre part (fig. 16): the line of the blow holes was again found along the separation of the zones.

A particular macrographical appearance is characteristic of « green » ingots, *i. e.*, ingots bloomed before the centre has completely solidified (fig. 17). The rolling has had the effect of driving out through pressure, the impurities contained in this spongy part in the same way as in the manufacture of puddled iron the impurities are got rid of by shingling: the central part is in this way cleared of these impurities which collect in contact with the metal already solidified.

It should be noted that the solidifica-

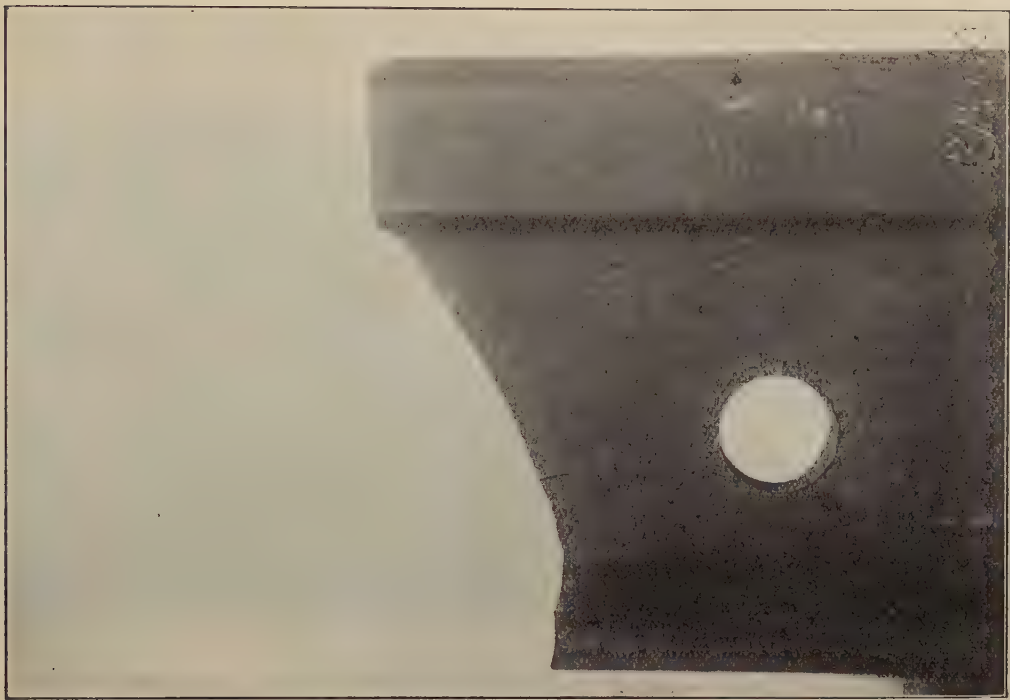


Fig. 7. — Rail with a complete transverse fracture.

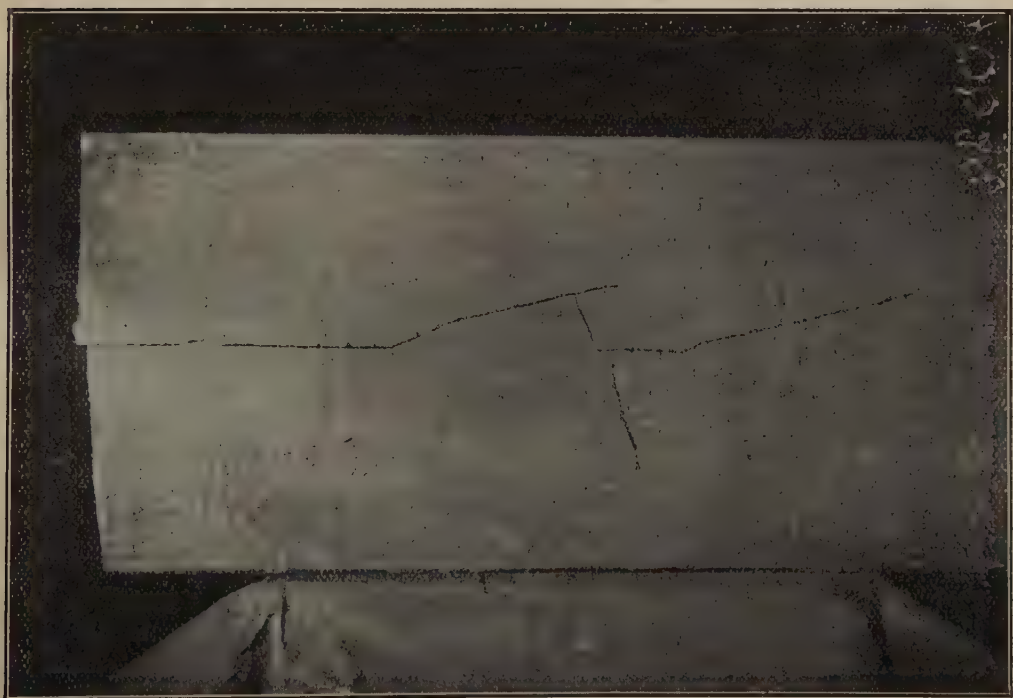


Fig. 8. — View taken from below the foot of the rail of figure 7.

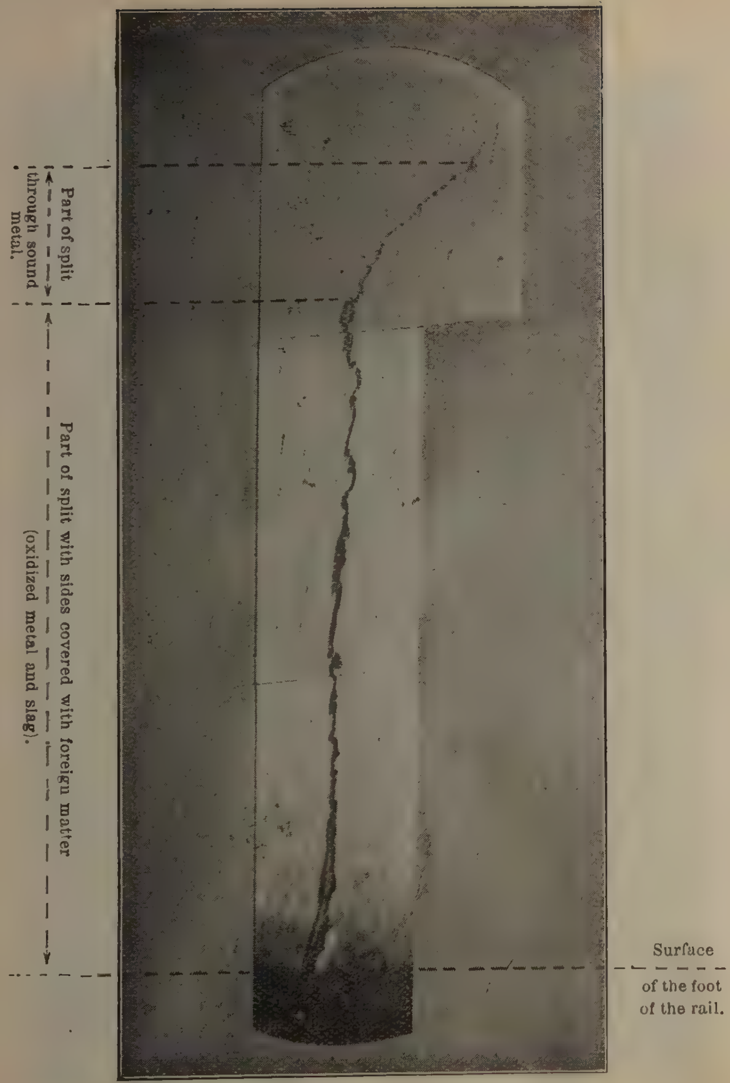


Fig. 9. — Micrograph, before etching by the reagent, of the split in the foot of a rail

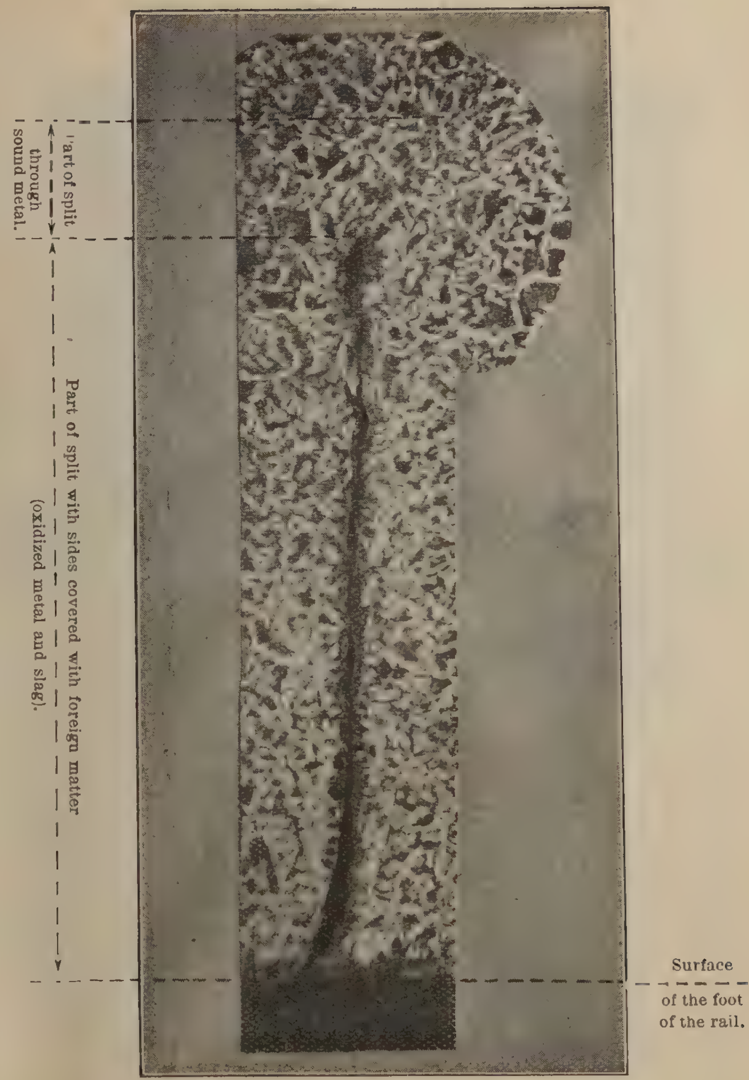


Fig. 10. — Micrograph, after etching by the reagent, of the split seen in figure 9

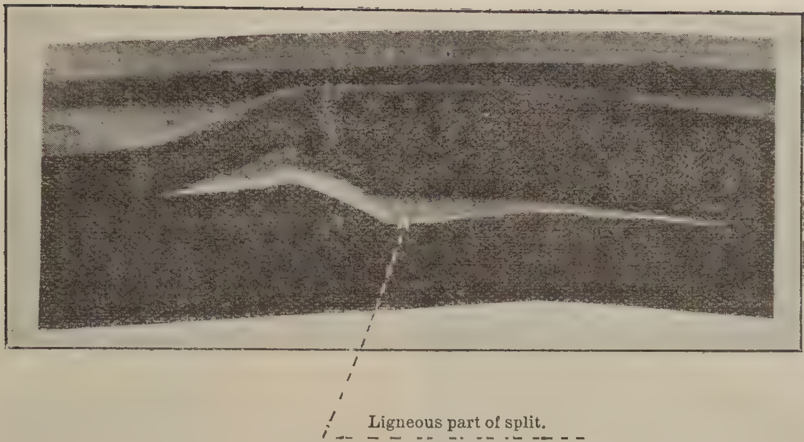


Fig. 11. — Photograph of the foot of a rail showing split of which the edges have a woody appearance (the opening out of this split has been enlarged in order to show up the edges better).

tion of the ingot can under certain conditions produce a centre part less rich in carbon and in sulphur than the surrounding part without it being correct to speak of a « green » ingot, but in this case if the centre part of the macrograph is lighter than the periphery of the profile, it is not edged by a ring of impurities as in the case of « green » ingots (fig. 18).

The solidification may even produce, in a still medium a series of concentric layers clearly differentiated by their colour on the macrograph, but without lines of impurities at the planes of separation of these layers (fig. 19).

Up to the present, it has not been found possible to find any relation between the appearance of the segregation and the defects recorded. Certain rails, badly segregated, wear and age in the track without any defect revealing itself whilst splits and breaking away of the head are found in rails showing only very slight segregation. One is led to wonder if the defects only arise when, prior to being laid in the track, the rail contains actual internal fissures started and already working through the sound metal, fissures set up, starting from the segregated nodules, by the considerable stresses produced in the rail during manufacture : rolling, cooling, cold straightening ?

5. Rails the fracture of which shows an oval stain.

The rails the joint Committee considered showed much segregation and there were considerable internal cavities in the metal in the segregated area : there was therefore no need to look for any other origin of the oval stain.

6. Rails the head of which showed superficial fissures.

Later on (pages 2049 and following the result of the examination of such rails will be given.

7. Rails the head of which is affected by corrugated wear.

Particulars will be given later on (pages 2067 et seq.) of the result of the examination of such rails.

Fig. 12. — Micrograph of rail at a point where it shows superficial rolling defects (enlargement 83 D).

§ 3. — *Have you inserted in your specifications any new requirements intended to protect the Company from receiving material showing segregation? What are they? What results have you obtained from them?*

Have your metallurgists devised any new processes to suppress or reduce segregation? What are they? and what results have they given?

The Belgian National Railway Company has specified since 1927 a minimum discard from the top of the ingot of 25 % and insists upon the rails being completely free from any piping or segregation. Actually, to get these results, the steel works discard over 25 % and up to 35 % in some cases.

The Egyptian State Railways have recently introduced into their specifications, a clause prescribing : *a*) that the ingot shall not be less than 200 square inches at the largest section; *b*) that it shall be kept in the upright position until completely solidified; *c*) that the discard shall be sufficient to completely eliminate all unsound portions of metal.

The principal French Railway Companies completed in 1928 the Standard Specifications of July 1923 by an addendum in accordance with which any rail clearly showing segregation is to be rejected. The rails are examined by macrography following the Baumann process.

Since this additional clause was brought into operation most of the makers have improved their manufacturing methods, especially as regards additions to the molten metal, and have increased the discard : some firms run the ingots upside down with or without dead heads. One steel works runs the moulds from below.

The application of the addendum is of too recent date for the results obtained to be correctly appreciated. It can however be said that the latest supplies as a whole from this point of view are improved.

The specifications of the *Société des Transports en Commun de la Région Parisienne (France)* require the discard from the rolled bar to be sufficient to eliminate the piping from the top of the ingot. In a recent addition to the specifications of this Company, the minimum silicon content is fixed at 0.25 % so as to obtain a quieter metal with higher values of the mechanical characteristics.

Rails with 1 to 1.5 % of silicon have been offered to this Company and a test is being made of them.

The Italian State Railways had introduced the macrographic test by etching (corrosion) before 1925 — this test originally carried out in the proportion of 1 per lot of 200 rails, is now carried out

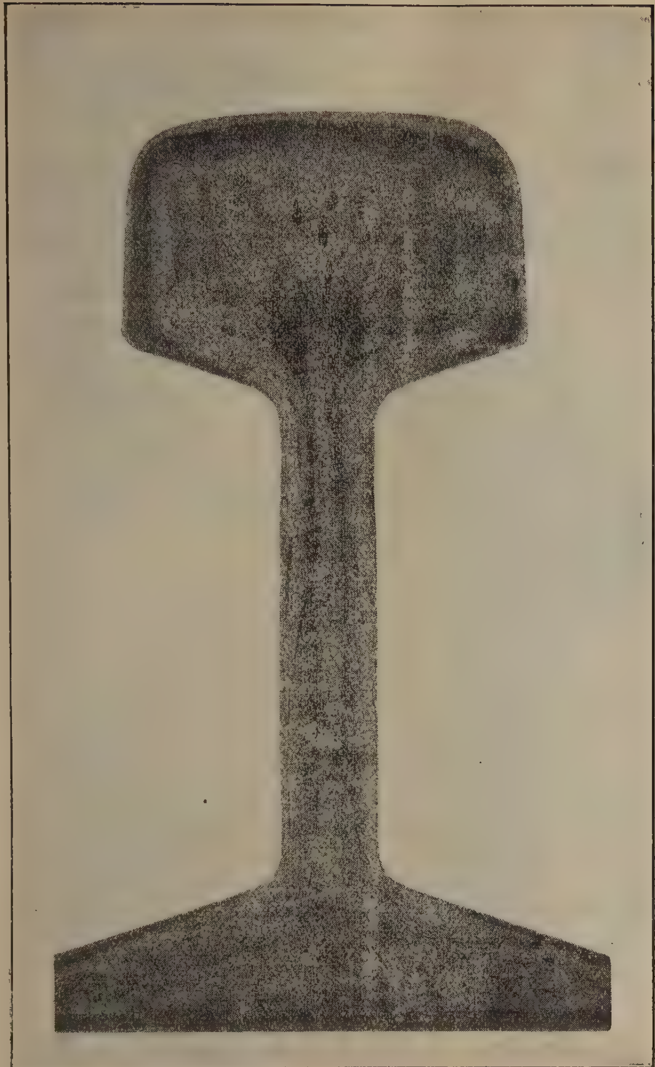


Fig. 13. — Macrograph in which the outside metal for a small depth appears with a lighter colour than the underlying metal.

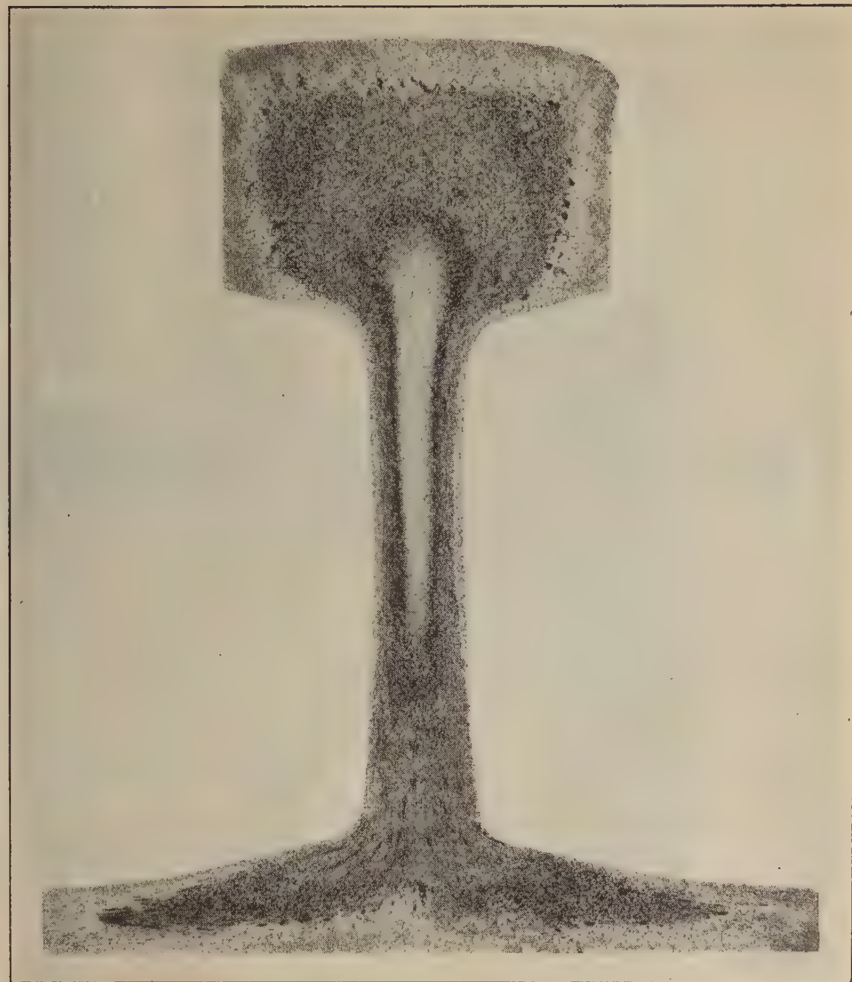


Fig. 14. — Macrograph in which the outside metal for a greater depth appears with a colour lighter than that of the underlying metal.

Fig. 15. — Photograph of a section of rail after an acid corrosion which produced the hollows in the metal at the points at which there were impurities.

on each cast and this Company considers it would be beneficial to make it on each ingot. To prevent rejections, the leading steel makers now discard from the top of each ingot weighing 3 500 kgr. (7 716 lb.) a billet of 1 000 kgr. (2 200 lb.) used for other purposes. Other makers pour the ingots inverted with dead heads.

The Rumanian State Railways specified a macrograph from the bottom of the discard from the top of each ingot. In order to reduce and possibly suppress segregation, the steel makers manufacture the rail from Martin steel with 0.20 % of silicon which has given very good results, and has considerably reduced the segregation. This Administration considers that its macrograph tests have resulted in an undoubted improvement in the quality of its rails.

Fig. 16. — Macrograph in which the outside metal appears with a deeper colour than the underlying metal.

The Czecho-Slovakian State Railways have specified since 1928 for each cast a drop test on a length of rail cut from the end of the rolled bar corresponding to the top of the ingot but do not prescribe any eliminating metallographical test.

Other Administrations, whilst admitting the need for eliminating the unsound part of the rails, have not altered their specifications in this respect since 1925.

We find several Administrations have tightened up the clauses of their Specifications dealing with the elimination of segregation or at least apply the existing requirements more rigidly.

The Belgian National Railway Company and the Italian State Railways appear to be the only ones who definitely refuse

Fig. 17. — Macrograph of a section of a rail rolled from a « green » ingot.

to accept any rails showing even the minutest traces of segregation.

Other Companies, and in particular the principal French Railways, and the Rumanian State Railways, without absolutely prohibiting any segregation, have fixed maximum limits based on the appearance of macrographs.

The steady tightening up of the Companies' Specifications with regard to this question, appears to have caused the Steel Makers either to take greater care during manufacture, or by increasing the top discard to reserve for rail making the really sound portions of the ingot.

This should result in an improvement in the quality of the rails : but these

Fig. 18. — Macrograph showing a central part lighter than the surrounding area, but without a ring of impure metal round the central part.

measures are of too recent introduction for it to be definitely stated that the results will be fewer defective or broken rails.

It would be most valuable if the Companies having introduced further precautions against segregation, would keep comparative statistics of rails manufactured to the old and new specifications, so as to bring out the value of the amendments.

§ 4. — *Have you extended the use of metallographical tests (macrography and micrography)? Do you carry out the tests for record purposes, or as rejection tests?*

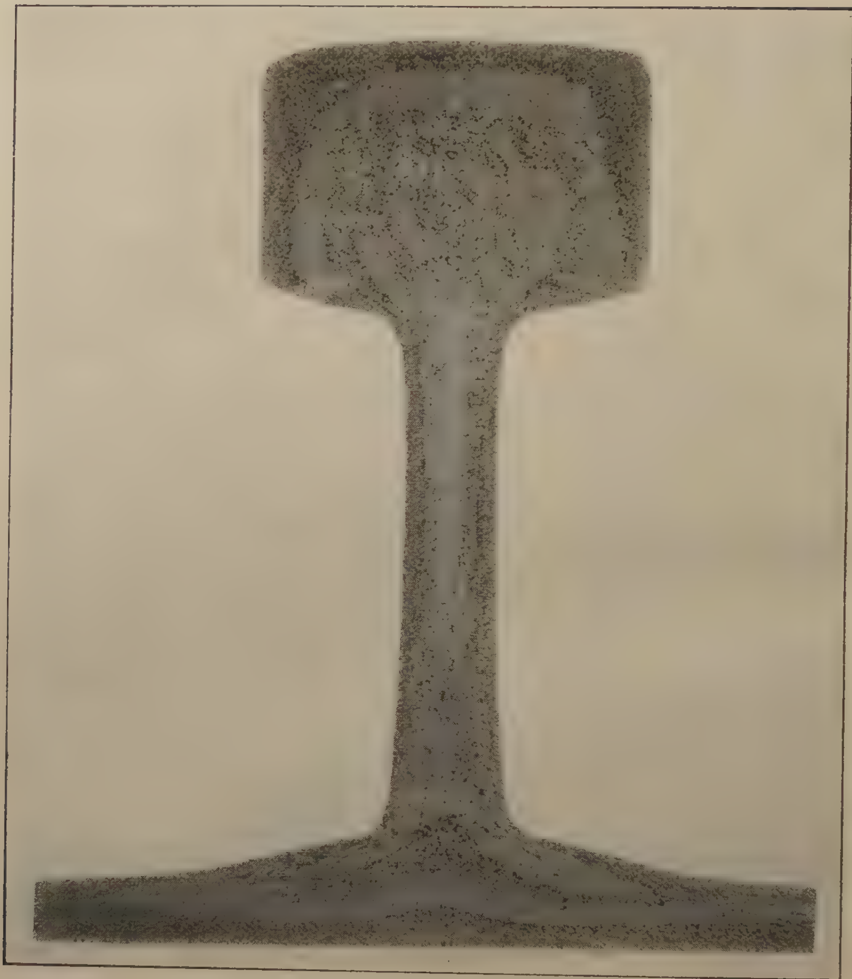


Fig. 19. — Macrograph showing a series of concentric layers of different shades, but without lines of impurities between them.

What are the reagents or etching solutions used for each of the two classes of test?

What are the reasons governing the selection of the reagents used?

a) *Macrographic test.*

If these tests are made for record purposes, what information have you obtained from them?

If they are rejection tests, do you allow impurities such as sulphur, phosphorus, non metallic inclusion, or soft metal to appear on the macrographs? If so, to what extent?

Otherwise said, what criterium do you use when accepting or rejecting rails, from the macrograph, and how do you justify the standard laid down?

b) *Micrographic tests.*

If these tests are made for record purposes what information have you obtained from them?

If they are rejection tests, what limits have you laid down?

The Belgian National Railway Company has carried out for a number of years metallographical tests and considers them a valuable means of ascertaining the initial cause of rail breakages. Various reagents are used : double chlorate of copper and of ammonium (Heyn reagent), iodine, pure hydrochloric acid, diluted sulphuic acid, for the macrographs : 4 % solution of pure picric acid in ethyl alcohol and the Kourbatoff reagent, for the micrographs.

The macrographs are taken with a view to eliminating defective rails : any rail showing even the most minute traces of segregation is rejected.

The micrographical tests are so far only used for record purposes, and are useful in revealing heat or work hardness, or decarburised areas.

The Bulgarian State Railways carry out macrographical tests for record purposes and find them of value, and are about the add them to their Specifications; they do not make any micrographical tests.

The Madrid to Saragossa and Alicante Railway has made some etching tests on a number of broken rails, using concentrated hydrochloric acid.

The North of Spain Railways are carrying out for record purposes a number of metallographical tests with the Baumann process for the macrographs and a 5 % solution of picric acid in alcohol for the micrographs.

These reagents were selected because of their ease of preparation and application.

By means of these metallographical tests the above mentioned Railway has succeeded in getting each rail maker to take the necessary precautions, so that its supplies are free from segregation either positive or negative : it considers their improvement as being particularly valuable for the rails containing 0.55 to 0.65 % of carbon and having to stand a severe drop test [1 000 kgr. (2 200 lb.) tup falling 5 m. (16 ft. 5 in.)] which previously 80 % failed to stand.

The principal French Railways as stated above, introduced in 1928 in their Standard Specifications and addendum prescribing the macrographical tests as a rejection test when inspecting rails.

This test is most often done by the Baumann process, sometimes with iodine or the solution of bichlorate of mercury in hydrochloric acid.

The Baumann process is prefered, owing to its simplicity.

The principal French Companies also carry out for record purposes, when investigating broken or defective rails, etching tests with hydrochloric acid and micrographical tests for which usually a mixture of alcohol and picric acid is used.

The Italian State Railways, as a rejection test take macrographs from each group of casts and recently from each cast. The micrographical test is only made for record purposes.

When making macrographs this Railway uses commercial hydrochloric acid of 24° Baumé strength at a temperature of 60 to 80° C. (140 to 176° F.) for 10 to

12 hours; or concentrated hydrochloric acid, bichlorate of mercury and water in equal quantities, cold, for 1/2 to 2 hours. For the micrographs it uses a 4 % solution of picric acid in ethyl alcohol.

The Rumanian State Railways have a specification which lays down a macrographical test as obligatory. The reagents used are : iodine or the Heyn. The former is preferred because it is more convenient in use and the image obtained is more visible and can be more easily photographed and reproduced.

The macrographical test is a rejection test, and no marked impurity should be visible on the macrograph; if the segregation stains are circular not more than 3 mm. (1/8 inch) in diameter and are placed near the neutral axis of the section of the rail, the rail is passed : if on the other hand the stains are larger or have a filamentous appearance or are in the head of the foot of the rail, the rail is rejected.

These Railways have furthermore issued certain data to guide the inspectors and to avoid argument upon the decision made.

This Railway System also considers that micrographical tests being rather of the nature of laboratory tests can not be practically used when inspecting rails.

The Swedish State Railways make for check purposes, macrographical tests when the results of the tests (mechanical and chemical) are not in agreement.

They intend to incorporate these tests in an early re-issue of the Specification.

The Swiss Federal Railways and the Bernese Alps Railway do not make metallographical tests, except for record purposes and do not purpose to introduce them in the near future.

The Czecho-Slovakian State Railways only make macrographical and micrographical tests in the case of rails broken in service.

They have however introduced as from January 1928, into their Specification a clause in accordance with which if the drop test or tensile test has shown any abnormal aspect of fracture, the Works shall as a matter of information and at the request of the inspector carry out metallographical tests.

In addition, a certain number of railway companies carry out macrographical tests in their laboratories when investigating rails broken in use, or found defective.

We find that except in the case of the Belgian National Railway Company, the main French Companies, the Italian State Railways and the Roumanian State Railways, the other administrations have not imposed macrographical tests on the result of which rails may be rejected. Whilst no railway specifies a micrographical test as a condition of acceptance, some of them carry out such tests for record purposes.

Macrographical tests.

The reagents used appear to be the double chlorate of ammonium and of copper (Heyn process), iodine, hydrochloric acid (corrosion tests), and finally diluted sulphuric acid (Baumann process) as preferred.

The Baumann process seems to be the simplest and quickest of them all. It shows up the segregation, positive and negative very clearly. It is the process that seems to be most suitable for use when the number of tests becomes great

and especially when macrography is used as a rejection test. It has the drawback that it does not lend itself well to photographic reproduction and from this point of view in laboratory investigations the Heyn process, iodine, and hydrochloric acid, are more suitable.

Some Railway Companies who only take macrographs for record purposes have found them of sufficient value to consider their inclusion as rejection tests, in their Specifications.

The Belgian National Railway Company and the Italian State Railways who use macrographical tests for rejection purposes, reject all rails in which these tests reveal even minute traces of segregation : the main French Railways and the Rumanian State Railways only reject those rails in which these tests clearly reveal marked segregation.

The principal French Companies do not object to traces of segregation (positive or negative) provided they are in the web and the base of the head : they will not accept the presence of metallic inclusions foreign to the metal of the cast.

The principal French Companies consider it would also be wise for the moment to limit the scope of the macrographical tests so as to allow on the one hand, the Companies to pursue their investigations into the forms of segregation (as characterised by their macrographical tests) which more specially set up defects or fractures and on the other, the Makers to develop manufacturing and pouring methods by which to eliminate segregation.

Micrographical tests.

The reagents used are many although preference appears to be given to a solution of picric acid in ethyl alcohol.

These tests make it possible to ascertain with certainty the inclusions of steel foreign to the cast as well as decarbonised zones on the edges of certain rails.

They are of great value when investigating superficial fissuration of the head of the rail and show up hardened metal on the running surface.

They bring out by characteristic aspects, rewelds made in the metal during rolling : cracks in the ingots, cold shots, folds, etc.

They give indications as to the structure of the metal and make it possible to see the effect of systematically carried out heat treatment or accidental heat hardening.

They provide means for following the formation and propagation of internal splits in the metal and thereby make a valuable contribution to the study of the causes of fracture and defectiveness of rails.

We think that for these reasons they ought to be carried out as a general practice, in the laboratories of the Companies.

§ 5. — *Have you specified tests for brittleness on the rails or resilience tests on notched bars cut from the rails?*

For these latter, describe the method of selecting the test pieces, the dimensions of the test bars, the form and the depth of the notch.

Do you carry out these tests to obtain information or as rejection tests ? In the first case what information have you been able to draw? In the second, what tests must the rails comply with ?

The Belgian National Railway Company carry out for record puposes, resilience tests by means of the Charpy

30 Kg.-M. (217 foot-pounds) tup, on test pieces 10 × 10 (3/8 × 3/8 inch) with Mesnager notch (fig. 20). These test bars were cut out and notched originally as shown in figure 21 but are now notched at the point shown on figure 22.

Up to date these tests have covered more than 250 000 tons of rails : the graph given below (fig. 23) brings together the results obtained during the years 1926, 1927 and 1928.

From these numerous tests, the Belgian National Railway Company has drawn the following conclusions :

1. Everything else being equal, the resilience and, as a consequence, this strength against brittleness is improved by perfecting the temperature conditions of the rail metal from the time it is poured, until the completion of rolling. Stress should in particular be laid on the importance of the temperature at the completion of rolling.

2. It is not possible to make of the resilience test, a rejection test. It would, however, be possible to state beforehand the average or minimum resilience desired and grant premiums in the case of supplies with a resilience exceeding the values laid down; this would also encourage the steel works to take especial care during manufacture in order to raise the resilience of the rails supplied.

3. An investigation is required into the best form to give the resilience test piece and the notch, keeping in mind the real difficulty there is to obtain, when preparing the test bars, the correct finish without which the results may be spoiled by errors.

The Bulgarian State Railways have enquired into the question of resilience tests but think it would not be possible to reject rails on such tests.

The Madrid to Saragossa & Alicante Railways are of opinion that the resilience tests take too much time, and are not sufficiently practical to be required as a general rule.

The principal French Railways carry out, as a rejection test, a drop test on a milled section of rail (fig. 24) which, owing to the notch, constitutes a resilience test, the conditions of the test for the 46 kgr. (92.7 lb. per yard) rail being as follows :

Weight of tup 300 kgr (660 lb.);

Height of drop 4.60 m. (15 ft. 1 in.).

A test is taken from each ingot the test piece being taken from the lower side of the top discard from the said ingot.

The principal French Railways also carry out in their laboratories for record purposes resilience tests with the Charpy pendulum tup of 30 Kg.-M. (217 foot-pounds) and the Fromont tup on test pieces of 55 × 10 × 10 (2 3/16 × 3/8 × 3/8 inches) with Mesnager notch and on Fremont test pieces of 55 × 10 × 8 (2 3/16 × 3/8 × 5/16 inches) not notched (fig. 20).

These test bars are taken from the positions shown in figure 25.

The Société des Transports en Commun de la Région Parisienne (France) carry out as a rejection test, a drop test on a milled section of rail, as is done by the great French Railways.

The Gafsa Railway (Tunis) only makes brittleness tests in the case of rails which have broken in service. They use the 55 × 10 × 10 (2 3/16 × 3/8 × 3/8 inches) test piece with either the Mesnager or the Standard U. F. notch (fig. 20) and has found that where there is marked or relative fragility, segregation and impure metal also exists.

The Company operating the Tunisian Railways has, as a matter of information,

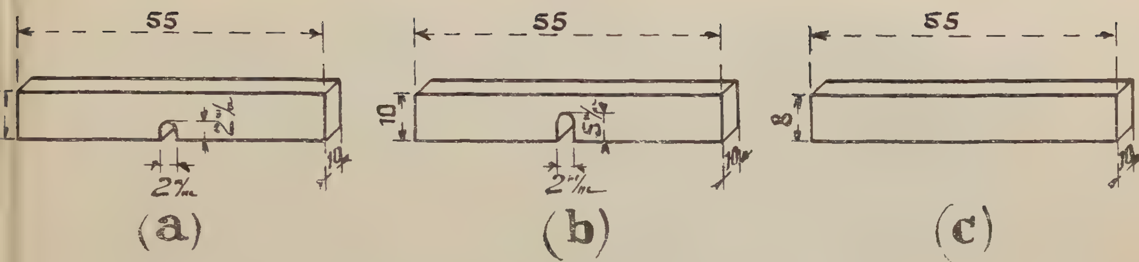


Fig. 20. — Test pieces for resilience tests : *a*) with Mesnager notch ; *b*) with Standard U. F. notch ; *c*) without notch, Frémont type.

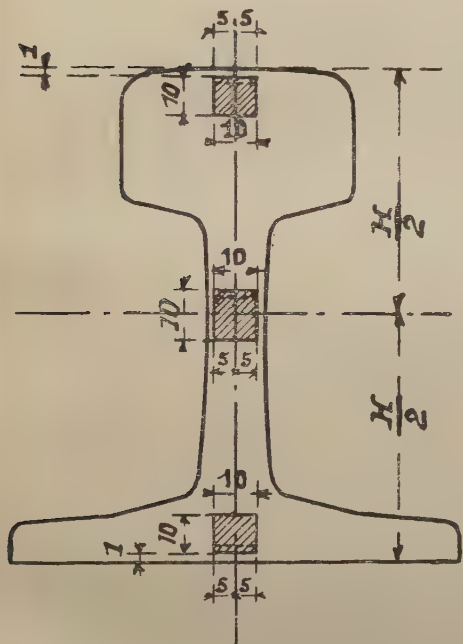


Fig. 21. — Belgian National Railway Company. — Positions from which resilience test pieces are cut out and locations of the notches on these test pieces when the test was introduced.

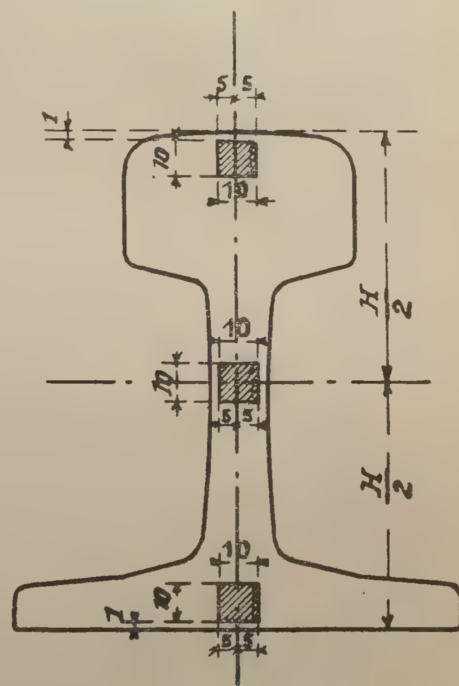
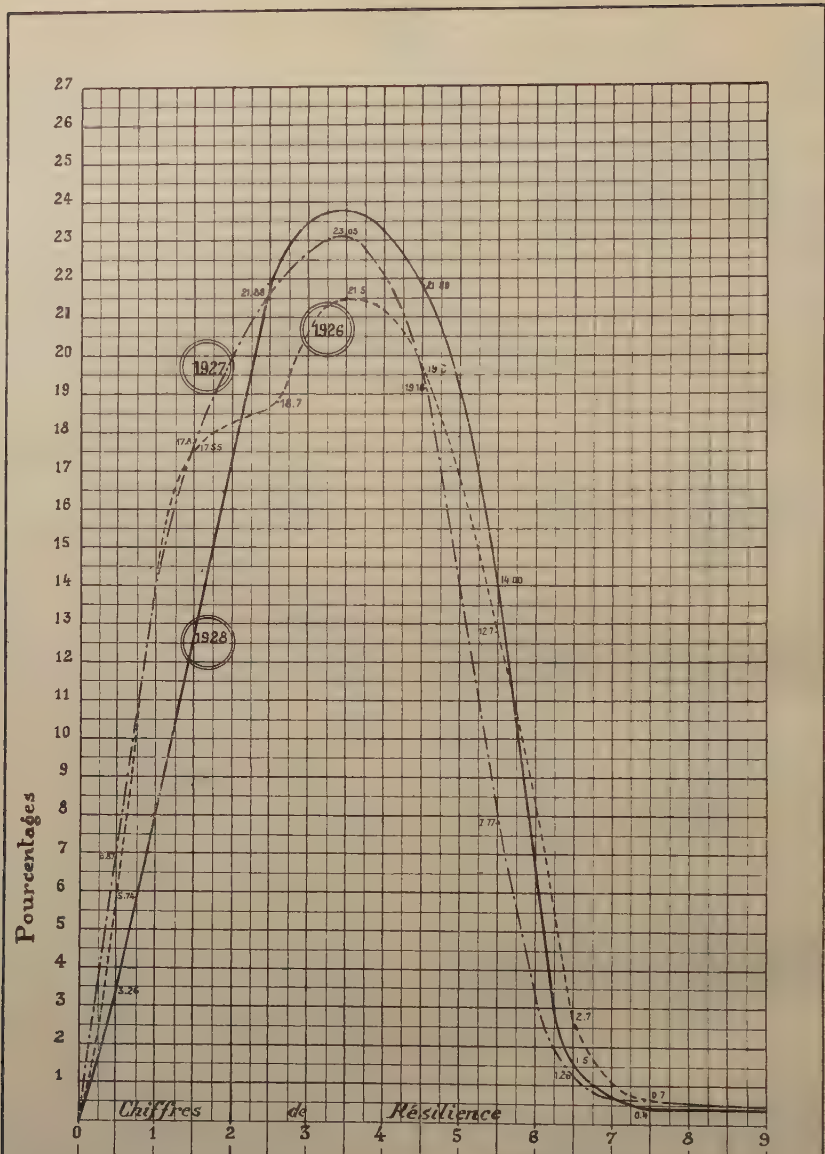


Fig. 22. — Belgian National Railway Company. — Positions from which the resilience test pieces are cut out and the present time location of the notches on these test pieces.

made some resilience tests on notched bars, 55 × 10 × 10 from rails taken out of service. The specification of this Company imposes the same drop test on milled rail as those of the great French Railways.

The Italian State Railways do not carry out any other rejection test for brittleness or resilience than the drop test specified in their Specification. As a matter of experiment, this administration makes resilience tests on 60 × 10 × 10



1926	5.74%	17.55%	18.7%	21.5%	19.5%	12.7%	2.7%	0.7%
1927	6.87	17.8	21.88	23.05	19.16	7.77	1.26	0.72
1928	3.26	12.23	21.80	23.75	21.80	14.00	1.5	0.4

Fig. 23. — Belgian National Railway Compagny. — Diagram giving results of resilience tests carried out on rails manufactured during the years 1926, 1927 and 1928.

Explanation of French terms : Chiffres de résilience = Resilience numbers. — Pourcentages = Percentages.

(2 3/8 × 3/8 × 3/8 inches) bars with the Mesnager notch the bars being cut from the positions shown in figure 26. It has so far drawn no conclusion from the information collected.

The Rumanian State Railways carry out the drop test on a milled end of rail as laid down in the French specification, but with a slightly higher drop.

The Swiss Federal Railways have as from January 1928, for record purposes, made resilience tests on Mesnager notched bars taken from the positions shown in figure 27. The results have varied and it has not been possible to draw any information from them so far.

The Czecho-Slovakian State Railways began in 1928 to carry out some resilience tests in their laboratory, using Mesnager notched bars of 10 × 10 (3/8 × 3/8 inch).

The other Railways in order to ascertain the brittleness of the rails, only use the drop test on a full section length of rail, a test which is always used as a rejection test.

We find that the Belgian National Railway Company, the great French Railways, the Italian State Railways, the Swiss Federal Railways, and the Czecho-Slovakian State Railways make for record purposes resilience tests, on small test bars either during the inspection of the rails, or when enquiring into causes of broken or defective rails. The Belgian National Railway Company has in particular carried out these tests systematically for several years on all the makes of rails it uses.

The test bar generally used is the notched bar of the Mesnager type. It is cut out from different parts of the rail section.

At the present time none of the Railways mentioned is in a position to introduce as a result of its resilience tests on small test pieces, an inspection test on which rails would be rejected.

The Belgian National Railway Company is considering however making the test serve as a method of classification of the rails on which premiums would be awarded the Makers.

The French Joint Committee on rails, has had whole ingots rolled out into rails and has examined the bars so obtained from one end to the other, after having them cut up into 1.10 m. (3 ft. 7 5/16 in.) lengths. Test pieces for resilience tests were taken from each piece at the points indicated in figure 25:

3 lengthways with Mesnager type notch,

1 crossways, unnotched, Frémont type.

The graphs below (figs. 28, 29, 30) show the value of the resilience from one end of the bar to the other for three of such rails rolled at three different works.

These graphs enable us to see that the resilience varies to a considerable extent from one point to another of the same section and from one section to the next section of the same bar.

These variations in the resilience are explainable by the fact that the test on notched bars is a test which deals entirely with a point, influenced by the heterogeneities of all kinds that metal may include although slight, and which are not revealed by macrography.

The deduction to be drawn therefrom is that it is difficult to characterise by the value of the resilience found at a point arbitarily chosen beforehand the absence of brittleness of a cast or even an ingot.

It would appear that to obtain a more

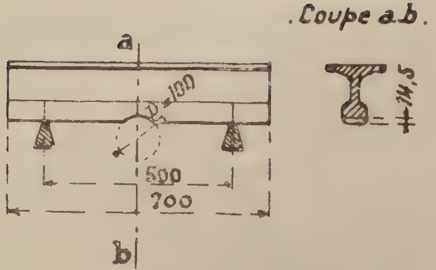


Fig. 24. — Main French Railway Companies. — Form and dimensions of the section of 46-kgr. (92.7 lb. per yard) rail used for the drop test.

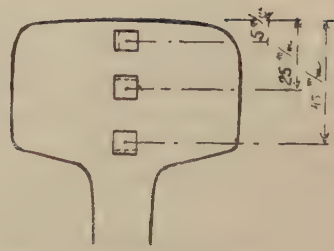
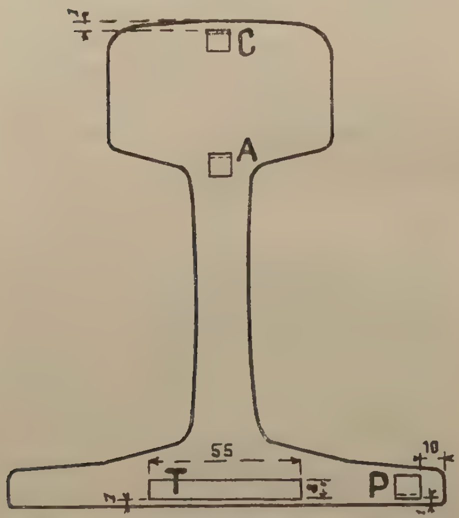
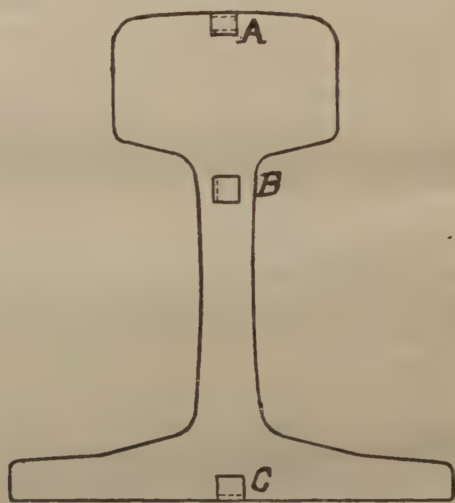


Fig. 26. — Italian State Railways. — Positions from which the resilience test pieces are cut out, and locations of the notches on the test pieces.



C. A. P. — 55 × 10 × 10 (2 3/16 × 3/8 × 3/8-inch) test piece with Mesnager notch.
T. — 55 × 8 × 10 (2 3/16 × 5/16 × 3/8-inch) test piece, not notched, Frémont type.

Fig. 25. — Main French Railway Companies. — Positon from which resilience tests pieces are cut out and locations of the notches on the test pieces.



N. B. — For each set of tests, two test pieces A notched respectively on top and below, one test piece B, and one test piece C are prepared.

Fig. 27. — Swiss Federal Railways. — Positions of the resilience test pieces and locations of the notches on the test pieces.

constant result, a much larger test piece would have to be used or even the full section of the rail.

The great French Railways have endeavoured to attain their objective to some extent by the drop test on milled rail.

We give below, as a matter of information, on the resilience graphs (figs. 28, 29 and 30), a curve of the drop tests made on the same short lengths, the ordinates being equal to the number of blows from the tup falling 4.60 m. (15 ft. 1 in.), the

piece of rail stood before breaking. It must be admitted that this is only an approximation and it would be of value if it were possible to install a testing machine of sufficient capacity, to register after breaking at the first blow a suitably notched length of rail, the kinetic energy remaining in the tup, and therefore to deduce as in the case of the Charpy pendulum the resilience of the metal.

As a step in this direction, Mr. Merklen, formerly Chief Engineer of the Alsace-Lorraine Railways has designed a new form of notch for full section rail. The extremely fine notch is 2/10th of a mm. (0.0079 inch) wide, and 15/10th of a mm. (0.0591 inch) deep.

It is cut by a fine saw driven as shown in figure 31.

A section of 46-kgr. (92.7 lb. per yard) rail the head of which has been notched in this way and subjected with the head in tension to a blow from a tup of 300 kgr. (660 lb.) breaks at heights of fall varying with certain steel rails between 0.5 to 3 m. (1 ft. 7 11/16 in. to 9 ft. 10 1/8 in.).

This test, on a rail notched in this way with a fine saw could conceivably be used to decide the award of premiums under consideration by the Belgian National Railway Company.

It would be necessary in this connection to make certain by making a series of tests over the whole length of an ingot rolled into rails, that the results of this test were sufficienlty constant when passing from one piece of rail to the next, and so could be taken as truly characteristic of the absence of brittleness in the ingot.

§ 6. — *Have you carried out tests with heat treated rails ? What results have you obtained ?*

Describe the treatment and give its principal characteristics. Explain the test method which has enabled you to satisfy yourself that the treatment has been done properly. In what position, and under what condition do you prefer to use, heat treated rails ?

The North of Spain Railways have under test rails treated by the Sandberg process (sorbitic rails).

The Sandberg process so called after its inventor, was described in detail in the January 1927 number of the *Revue de Métallurgie*.

With this process the heat treatment is carried out immediately after rolling.

The rail held stationary in plant designed for the purpose, is quenched by means of jets of water broken into fine spray by means of compressed air, at a rate which can be varied to suit the class of metal and the result desired. The treatment is stopped before the head of the rail is completely cooled down, and the heat remaining in the rail produces the reheating needed to suitably modify the effects of the hardening.

The great French Railways and the *Société des Transports en Commun de la Région Parisienne (France)* have tested on a rather large scale (several thousands of tons) heat treated rails either by the Sandberg process described above or more especially by the Neuves-Maisons process.

The Neuves-Maisons process, so named after the French steel works where it was invented and perfected, was described in the February 1926 number of the *Revue de Métallurgie*.

In this process the rail on leaving the rolling mill is held stationary head down, on rollers holding the foot upwards against a horizontal girder which forms the fixed support; a moveable tank longer

The diagram below represents:

As abscissae: the positions of the test pieces relatively to the end of the rail representing the head of the ingot; the figures of the upper line show the numbering of these positions; those of the lower show the position of the test piece as a percentage of the length of the rail.

As ordinates:

1. The values of the resilience obtained with test pieces cut out lengthways from the head (C), in the web (A), and in the foot (P) of the rail and taken across (T) the foot:

2. The number of blows from the tup (weight 300 kgr. = 660 lb. — drop 4.60 m. = 15 ft. 1 in. — supports 0.50 m. = 1 ft. 7 11/16 in. apart) taken before fracture by milled
15 ft. 1 in. — supports 0.50 m. = 1 ft. 7/16 in. apart) taken before fracture by milled

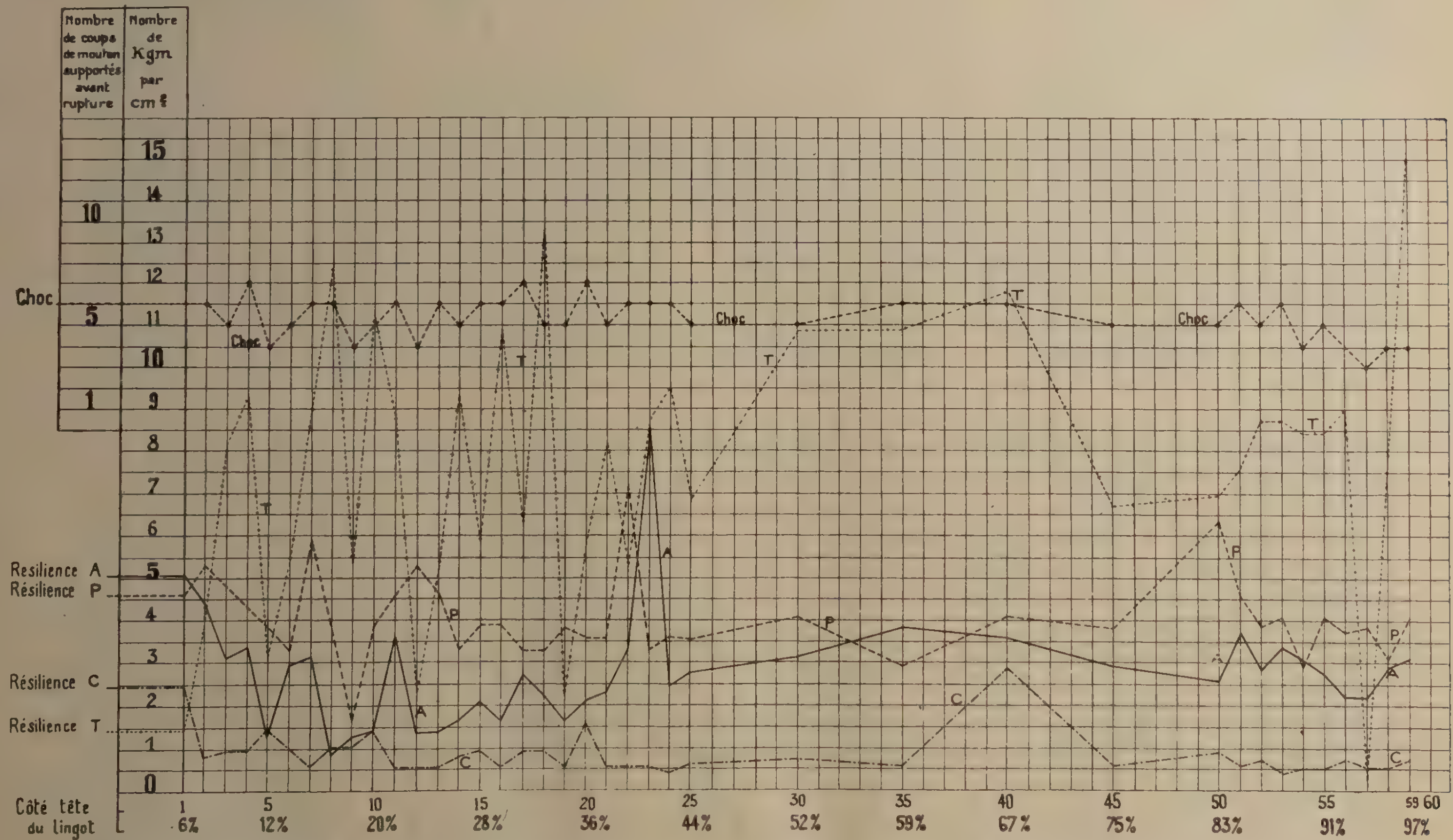


Fig. 28. — Diagram giving the results of resilience tests and drop tests carried out from one end to the other of the rail attained after rolling into rails of complete A ingot.

Explanation of French terms in figs. 28, 29 and 30: Côté tête du lingot = Head of ingot on this side. — Nombre de coups de mouton..... = Number of blows from the tup before breaking. — Nombre de kgm. par cm² = Number of kilogrammetres per square centimetre.

The diagram below represents:

As abscissae: the positions of the test pieces relatively to the end of the rail representing the head of the ingot; the figures of the upper line show the numbering of these positions; those of the lower show the position of the test piece as a percentage of the length of the rail.

As ordinates:

1. The values of the resilience obtained with test pieces cut out lengthways from the head (C), in the web (A), and in the foot (P) of the rail and taken across (T) the foot;

2. The number of blows from the tup (weight = 300 kgr. = 660 lb. — drop 4.60 m. = 15 ft. 1 in. — supports 0.50 m. = 1 ft. 7 11/16 in. apart) taken before fracture by milled lengths of rail drop tested with the head in tension.

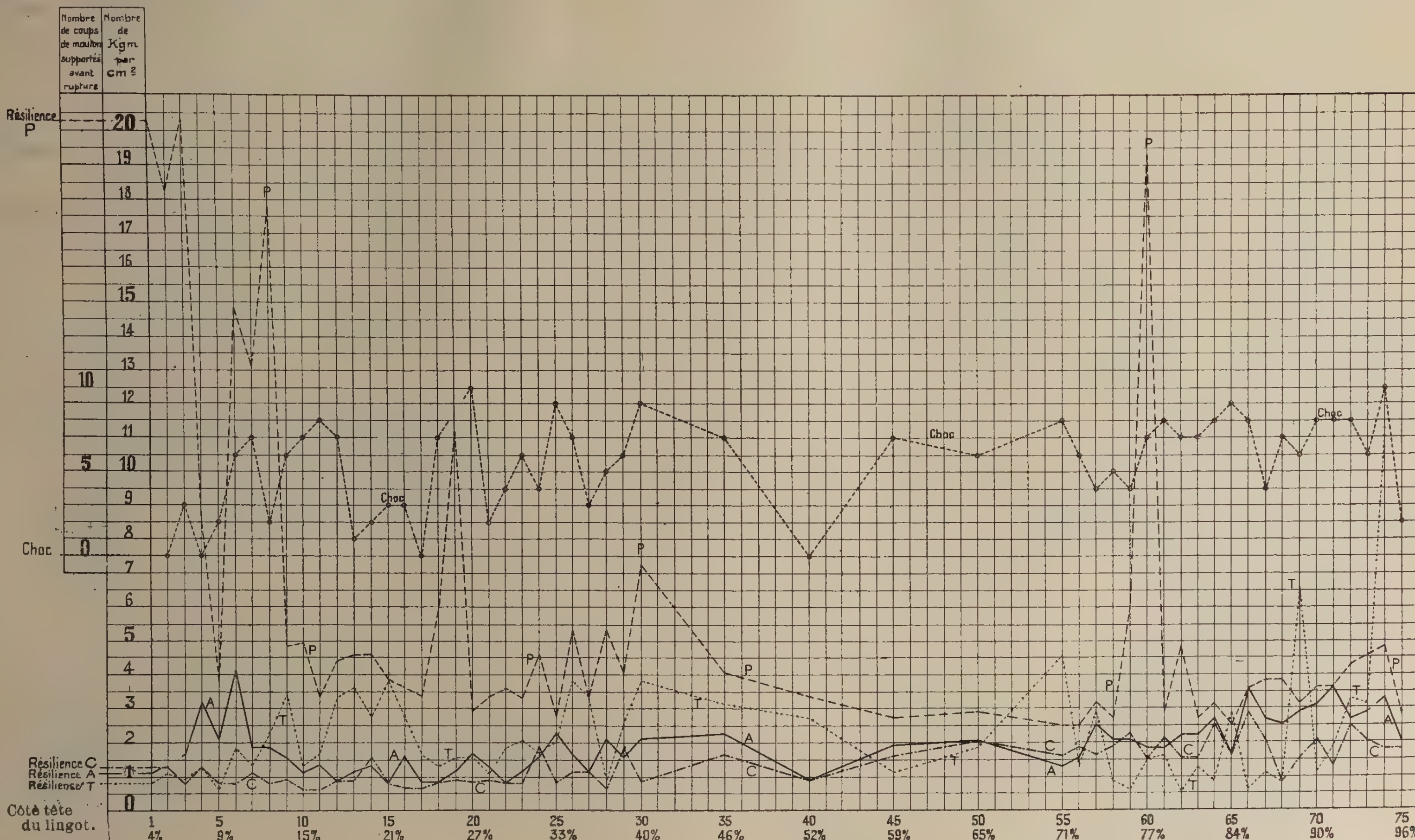


Fig. 29. — Diagram giving the results of resilience tests and drop tests carried out from one end to the other of the rail attained after rolling into rails of a complete B ingot.

The diagram below represents:

As abscissae: the positions of the test pieces relatively to the end of the rail representing the head of the ingot; the figures of the upper line show the numbering of these positions; those of the lower show the position of the test piece as a percentage of the length of the rail.

As ordinates:

1. The values of the resilience obtained with test pieces cut out lengthways from the head (C), in the web (A), and in the foot (P) of the rail and taken across (T) the foot;

2. The number of blows from the tup (weight = 300 kgr. = 660 lb. — drop 4.60 m. = 15 f. 1 in. — supports 0.50 m. = 1 ft. 7 11/16 in. apart) taken before fracture by milled lengths of rail drop tested with the head in tension.

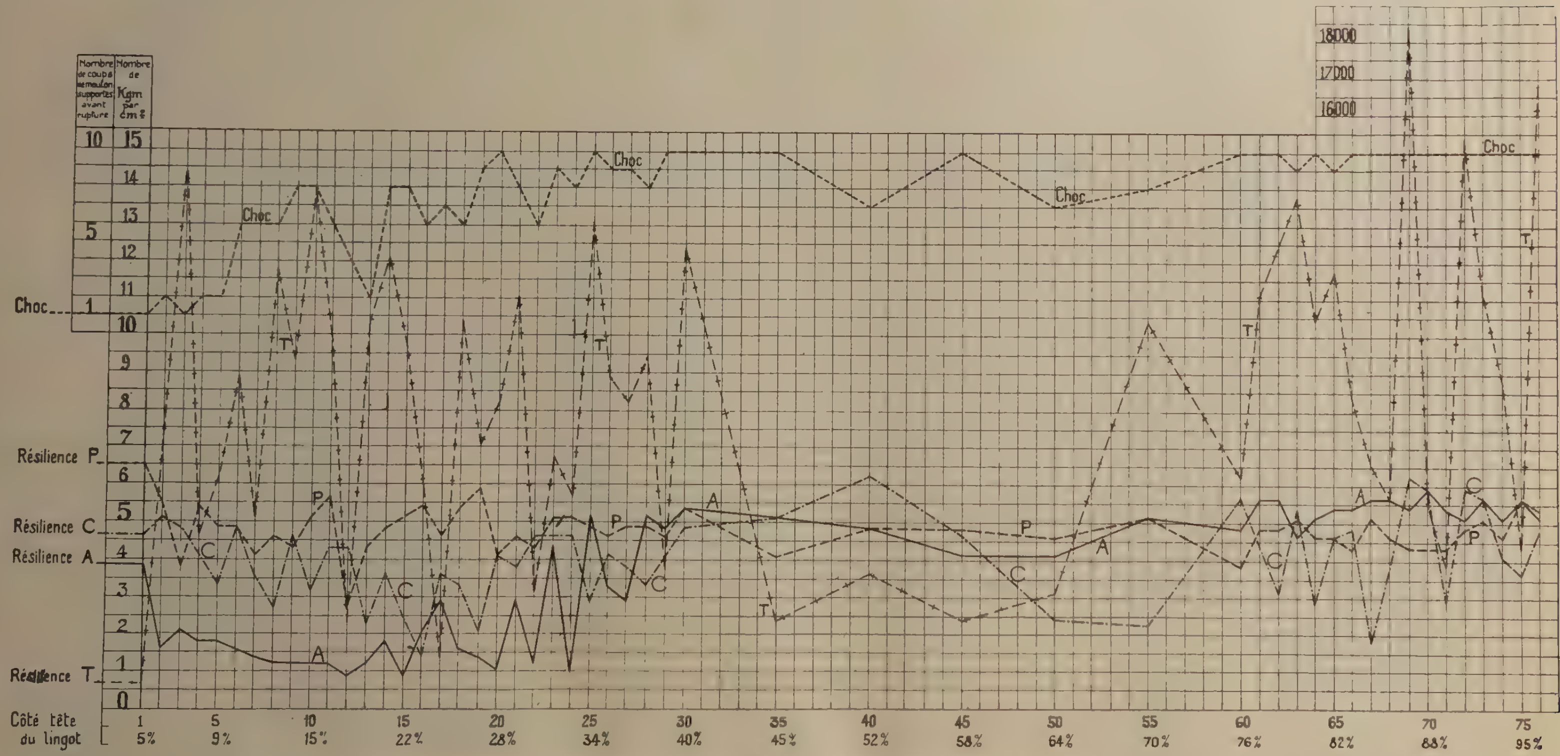


Fig. 30. — Diagram giving the results of resilience tests and drop tests carried out from one end to the other of the rail attained after rolling into rails of a complete C ingot.

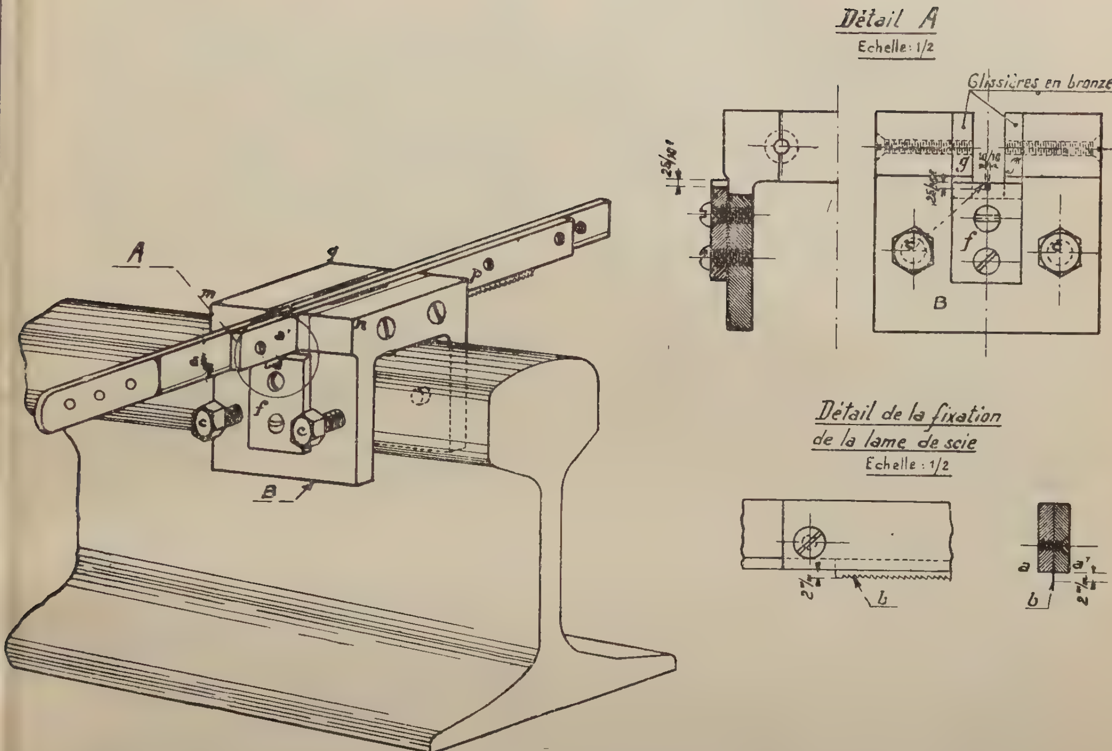


Fig. 31. — Apparatus for notching rails with a fine saw (Merklen notch).

Explanation of French terms : Détail A. Echelle : 1/2 = Details at point A. Scale : 1/2. — Détail de la fixation de la lame de scie = Arrangement for mounting saw blade. — Glissières en bronze = Brass sliding piece.

in length than the rail, filled with water and set under the rail is given an alternating upwards and downwards motion in such manner that a part as desired of the head can be submitted to a series of successive quenchings separated by reheating due to the heat retained in the remainder of the head, the web and the foot of the rail.

The quantity of water in the tank varies with the weight of rail to be treated, and thereby limits almost automatically the degree of hardening by the progressive heating up of the water during the operation. A feed pipe in the bottom of the tank drilled with small holes close together makes up any loss of water by splash or evaporation and makes it possible to regulate the degree of hardening according to the quality of the steel in the rail undergoing treatment and according to the hardness desired.

The number and frequency of successive dippings, the relative duration of the immersions and the time out of the water, are also factors which can be regulated and in consequence, the final hardening of the treated rails can be varied as described between very wide limits.

The treatment is stopped before the head of the rail is completely cooled off

and the rail, pushed clear of the plant is moved on to gratings where it cools off under normal conditions.

Heat treated rails have been laid either at places where locomotives habitually slip (near signals, stopping places) or where the rail wear is greatest (rails on curves). The tests of these rails are of too recent date for the railways to be able to form any definite conclusions from them: the point should however be stressed, that not a single breakage has occurred up to the present with heat treated rails, in spite of the fact that they have been placed at the most highly punished parts of the track.

Heat treated rails appear to wear better than untreated rails.

The results obtained in this respect will be dealt with on page 2084 of the report.

The *Société des Transports en Commun de la Région Parisienne (France)* have laid the rails at places in the track showing corrugated wear. So far these rails do not appear to resist this kind of wear any better than non treated rails.

The Italian State Railways have also carried out laboratory tests on rails treated by the Neuves-Maisons process.

The Swiss Federal Railways laid in 1928, 115 tons of 46-kgr. (92.7 lb. per yard) rails heat treated, 30 tons by the Sandberg process, 55 tons by the Neuves-Maisons process, and 30 tons by the Maximilianhütte (Bavaria) process. These rails have been laid on the outer side of curves of 300 m. (15 chains) radius on rising gradients of 26 and 27 mm. par m. (1 in 38 and 1 in 37).

In the Maximalianhütte process which has taken its name from the Bavarian works using it, the rail, on leaving the rolls, is fastened head downwards to the lower surface of a rigid horizontal girder which acts as a support and prevents the rail from getting out of shape.

The head of the rail is then quenched in cold water without the web and foot being immersed, the required annealing of the head being due to the heat retained in them. The operation consists of one single immersion which lasts as long as is needed to obtain the desired thickness of the hardened layer.

The length of this immersion is in addition a function of the temperature of the rail, of the chemical composition of the steel from which it is made, and of the temperature of the water; one to two minutes must be allowed to obtain a hardened layer of 6 to 8 mm. (1/4 to 5/16 inch) thickness.

We find that except for the *Italian State* Railways who only make laboratory tests, and the *Swiss Federal* Railways who have laid a short length for test purposes, the great French Companies are alone in using on a rather large scale heat treated rails.

It must be pointed out that the reason why these railways have taken this step, is to be found in the anxiety they felt as a result of breakages of rails after superficial fissurations of the head at places at which slipping or braking occurred (fig. 32) and because the result of the very violent slipping tests with a locomotive to which rails treated by the Neuves-Maisons method were subjected appeared to be that such rails even if they did not offer any resistance to the formation of superficial fissuration through slipping or brake action, are at least much less brittle when showing fissuration than untreated rails.

The tests and the results obtained were published in the *Revue de Métallurgie* (September, October, and November 1927 numbers).

At the end of the long series of methodically carried out tests the French Joint Committee on rails formulated the following conclusions :

1. The transverse superficial fissures of rails are serious defects which occur especially in places subjected to the slipping of locomotives, or to the braking of trains on rails the running surface of which has been hardened either through self heat hardening, or through cold work hardening. The formation of the fissures is facilitated if the heat produced by the friction of the wheels brings the running surface up to a blue heat.

2. The transverse superficial fissures show themselves in the form of a nick, the bottom of which is very sharp.

During the Neuves-Maisons tests they produced, when of equal dimensions, in the rails, the same brittleness whether the rails were self heat treated or work hardened.

3. The fissures can be set up in steels of all grades and qualities : they seem to occur more easily and be able to attain quickly large dimensions in a layer of hard steel very greatly heat hardened through prolonged slipping: but they also develop in mild steel of 40-45 kgr. (25.4 to 26.8 Engl. tons per square inch) tensile and make rails of this grade very fragile if they have not been heat treated.

4. The micrographical examination of the fissured rails show that segregation and inclusions facilitate the propagation of the fissures but these defects develop equally in good quality and very homogeneous steels and rails cannot be guaranteed against superficial fissuration by solely carrying much further than has been done so far the elimination of the impurities, non-metallic inclusions and segregation.

5. If it is not possible to prevent the formation of transverse superficial fissurations by using in rail making highly purified steel and steel so mild as not to harden under the effect of slipping, the dangers of fissure can at least be lessened in a marked degree, and rails can be made capable of standing up to operating conditions much more severe than at present. To obtain this result steps must be taken to deal with the chemical composition and the homogeneity of the rail steel, and also with the texture by submitting the bars on leaving the rolls to an appropriate heat treatment.

As the result of these definite conclusions, the great French Railways have extended the use of heat treated rails.

They then found it necessary to define a method of testing which would enable the efficacy of the heat treatment to be ascertained. Drop tests were made with a tup of 300 kgr. (660 lb. on a piece of rail 70 cm. (2 ft. 3 1/2 in.) long notched with a fine saw according to Mr. Merklen's method (page 2043) resting on supports 0.50 m. (1 ft. 7 11/16 in.) apart, taken from a number of successive batches of rails with this object in view and as a matter of experiment.

This test consists of 10 blows from a height of 0.50 m. (1 ft. 7 11/16 in.) the rail being turned over after each blow; 10 blows from 1 m. (3 ft. 3 3/8 in.) under the same condition : then with the head down 1 blow from 2 m. (6 ft. 6 3/4 in.) 1 blow from 3 m. (9 ft. 10 1/8 in.) and so on to fracture.

Tests were made on two lengths from each of the rails selected, one as rolled (untreated) and the other treated.

As a general rule the lengths of as rolled (untreated) broke during the series of blows from 0.50 m. (1 ft. 7/16 in.).

Not a single treated piece broke during this series of blows from 0.50 m. most of them standing the blows from 1 metre and some not breaking until the height

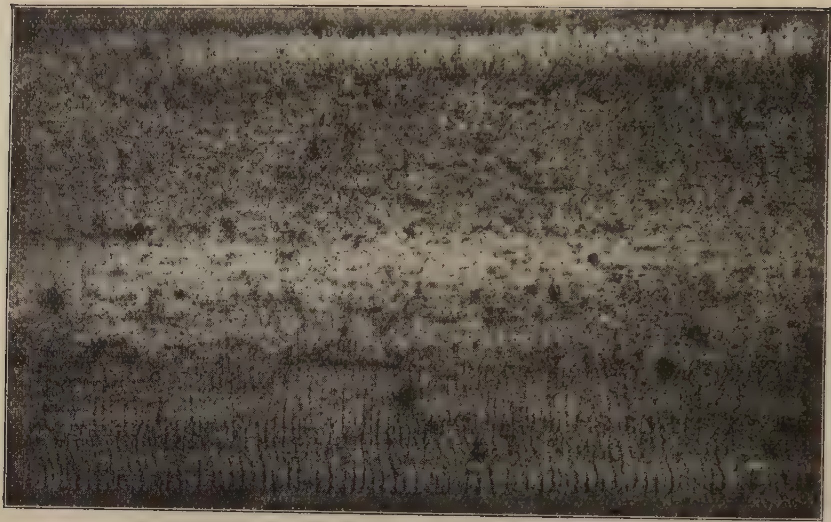


Fig. 32. — Rail showing superficial fissures. (In order that these fissures may be reproduced on paper the French Midi Railway Company recommend the method that they have used for the last 15 years, and which consists in rubbing the running surface of the rail with sulphate of baryum in powdered form, this powder penetrating into the fissures, and then to apply on this surface after removing the excess powder, photographic paper previously soaked in water made acid with sulfuric acid. By the action of the acid sulphuretted hydrogen is released and acting on the bromide of silver in the photographic paper, forms on the paper, in line with each fissure, a black line of sulphate of silver. The paper is then fixed, and washed, and a very clear macrographic print is thus obtained. The figure above is the photographic reproduction of a macrograph so obtained.)

of drop was increased up to 4 m. (13 ft. 1 1/2 in.).

We think it will shortly be possible to lay down a method of inspection based on the above experimental work.

§ 7a. — *What improvements have you introduced as regards the way in which the rails are used, with a view to reducing the number of broken rails?*

Have you increased the weight of rails used?

What weight per metre run do you consider needed for the axle weights with which you have to deal?

The Belgian National Railway Company now only order one pattern of rail which weighs 50 kgr. per metre (100.8 lb. per yard).

The Belgian National Light Railway Company has replaced the 23-kgr. (46.4 lb. per yard) rail by the 32-kgr. (64.5 lb. per yard).

The Bulgarian State Railways are replacing the 31-kgr. (62.5 lb. per yard) rail they used by a 41-kgr. per m. (82.7 lb. per yard) rail.

The Danish State Railways have increased the weight of the rails used and now use:

22.5-kgr. (45.3 lb. per yard) rails per axle load of 11 tons.

32-kgr. (64.5 lb. per yard) rails per axle load of 13 tons.

37-kgr. (74.6 lb. per yard) rails per axle load of 15 tons.

45-kgr. (90.7 lb. per yard) rails per axle load of 16 tons.

The Egyptian State Railways have replaced the 37-kgr. (74.6 lb. per yard) rails by 42, 46, and 47-kgr. rails (84.7, 92.7 and 94.7 lb. per yard).

The Central of Aragon Railway (Spain) has substituted the 42.5-kgr. (85.7 lb. per yard) rail for the 31-kgr. (62.5 lb. per yard).

The Madrid to Saragossa and Alicante Railway has used for some considerable time the 45-kgr (90.7 lb. per yard) rail which has been found to be strong enough.

The Medina del Campo to Zamora and Orense to Vigo Railways (Spain) have replaced the 32.5-kgr. (65.5 lb. per yard) rails by 42.5-kgr. (85.7 lb. per yard).

The North of Spain Railways have replaced the 30 to 32.5-kgr. (60.5 to 65.5 lb. per yard) rails with the 42.5-kgr. (86.7 lb. per yard) rail.

The Finish State Railways have increased the weight of rail used and are now enploying :

22 to 25-kgr. (44.3 to 50.4 lb. per yard) rails for axle loads of 12 tons.

30 to 33-kgr. (60.5 to 66.5 lb. per yard) rails for axle loads of 14 to 15 tons.

43-kgr. (86.7 lb. per yard) rail for axle loads of 18 to 20 tons.

The great French Railways (excepting the Midi) use as a general rule the 46-kgr. (92.7 lb. per yard) rail for their main lines with heavy traffic. The Midi Railway uses a 44-kgr. (88.7 lb. per yard) bull headed rail on certain tracks with heavy traffic; the State Railways use a 50-kgr. (100.8 lb. per yard) rail.

On lines in tunnels the great French Lines use as a rule 55-kgr. (110.9 lb. per yard) rails. On the secondary trunk lines they are steadily replacing their light rails (30 kgr. = 60.5 lb.) by 36 to 40-kgr. (72.6 to 80.6 lb. per yard) rails.

The Société des Transports en commun de la région parisienne (France) has not increased the weight of the rails used and still uses the grooved 52-kgr. (104.8 lb. per yard) U. V. F. L. rail on roads, the 46-kgr. (92.7 lb. per yard) Vignoles rail when laid alongside the roads.

The Algerian State Railways are gradually changing over from 25-kgr. (50.4 lb per yard) to 46-kgr. (92.7 lb. per yard) rails.

The Algerian lines of the Paris, Lyons and Mediterranean Railway Company have standardised the 46-kgr. rail which appears to be ample for the 19-ton axle loads allowed.

The Gafsa Railway (Tunis) has not increased the weight of the rails used and continues to use 25.25-kgr. (55.4 lb. per yard) rails which rail is found ample for the axle load of 10 tons.

The Tunisian Railway Company has increased the weight of the rails used to 46 and 36 kgr. (92.7 and 72.6 lb.) for standard gauge lines and 36 and 26 kgr. (72.6 and 52.4 lb.) for narrow gauge lines.

The respective axle weights are 10 and 11.5 tons.

The Italian State Railways have not increased the weight of rail used and continue to use 36, 46, and 50-kgr. (72.6, 92.7 and 100.8 lb.) rails.

The Guillaume-Luxembourg Railways and the Prince-Henry Railways and Mines Company (Luxembourg) employ the 46.2-kgr. (92.9 lb.) rail for lines carrying

heavy traffic and the 38.5-kgr. (77.6 lb.) rail for lines with light traffic.

The Norwegian State Railways use :

25-kgr. (50.4 lb. per yard) rail for axle loads of 10 tons.

30-kgr. (60.5 lb. per yard) rail for axle loads of 12 tons.

35-kgr. (70.6 lb. per yard) rail for axle loads of 15 tons.

40-kgr. (80.6 lb. per yard) rail for axle loads of 18 tons.

49-kgr. (98.8 lb. per yard) rail for axle loads of 20 tons.

The Netherlands State Railway Company and the Dutch Railway Company have during the last 16 years increased the weight of the rails used which now are :

38-kgr. (76.6 lb. per yard) rail for axle loads of 16 tons.

42-kgr. (84.7 lb. per yard) rail for axle loads of 18 tons.

46-kgr. (92.7 lb. per yard) rail for axle loads of 20 tons.

The Roumanian State Railways have increased the weight of their rails which now are :

45.25-kgr. (91.2 lb. per yard) rails for axle loads of 20 tons.

35.65-kgr. (71.9 lb. per yard) rails for axle loads of 14 to 16 tons.

The Swedish State Railways use rails weighing 25 to 43 kgr. (50.4 to 87.1 lb.) and have a formula for determining the weight as a function of the speed, of the axle load, and of the spacing of the sleepers.

The Serbian State Railways have increased the weight of the rails, and now use :

45-kgr. (90.7 lb.) rail for axle loads of 20 tons.

35-kgr. (70.6 lb.) rail for axle loads of 14 to 16 tons.

The Swiss Federal Railways use 42-kgr. (84.7 lb. per yard) rails for lines in the open, and 49-kgr. (98.8 lb. per yard) rails for lines in tunnel. The 36-kgr. (72.6 lb. per yard) rails still in existence are now being replaced and will have been taken out of the main lines by 1930.

The Czecho-Slovakian State Railways have increased the weight of rails used and now use 35.65 kgr. (71.9 lb.) and 44.35-kgr. (89.4 lb.) for lines in the open and lines in tunnels respectively.

We find that most railways are using heavier rails and use at least two weights.

On lines with moderate traffic the rails weigh as a rule from 36 to 42.5 kgr. (72.6 to 85.7 lb. per yard).

On lines with heavy traffic the weight is generally from 45 to 50 kgr. (90.7 to 100.8 lb. per yard).

The use of 50-kgr. rails is unusual on the different railways except in the case of the Belgian National Railway Company where it is standard.

Apart from strengthening up the section it seems to us that the breakages and defects occurring in service can be reduced by reserving rails made from the top of the ingots, usually of less good quality than rails from the middle and bottom, for use on parts of the line where the stresses are lower, for example on the straight or where speed is reduced.

In the same train of thought, arrangements could probably be made to lay the rails from the top of the ingot with the end of the rail which was nearest to the top of the ingot and which is possibly the least good at the least stressed side of the joint, namely the rail the wheel *leaves* when running forward.

§ 7*b*. — *What number of sleepers* **per kilometre** *do you use with each type of rail ?*

Do you vary the number of sleepers according to the density of traffic ?

Belgian National Railway Company :

1 389 sleepers (2 235 per mile);

1 500 sleepers (2 414 per mile) or

1 611 sleepers (2 593 per mile) according to the density of traffic.

Belgian National Light Railway Company :

1 250 sleepers (2 012 per mile) for the 23-kgr. (46.4 lb. per yard) rails.

1 111 sleepers (1 788 per mile) for the 32-kgr. (64.5 lb. per yard) rails.

Bulgarian State Railways :

1 250 sleepers (2 012 per mile) with the old 31-kgr. (62.5 lb. per yard) rails.

1 333 sleepers (2 145 per mile) with the new 41-kgr. (82.7 lb. per yard) rails.

The sleepering is the same on all lines and does not vary with the density of traffic.

Danish State Railways :

1 420 sleepers (2 285 per mile) for the 22.5-kgr. (45.4 lb. per yard) rails.

1 366 sleepers (2 198 per mile) for the 32-kgr. (64.5 lb. per yard) rails.

1 400 sleepers (2 253 per mile) for the 37-kgr. (74.6 lb. per yard) rails.

1 667 sleepers (2 683 per mile) for the 37-kgr. (74.6 lb. per yard) rails.

1 600 sleepers (2 575 per mile) for the 45-kgr. (90.7 lb. per yard) rails.

The number of sleepers is varied with the traffic with the 37-kgr. (74.6 lb.) rail only.

The Egyptian State Railways :

1 250 to 1 500 sleepers (2 012 to 2 414 per mile) according to the rail section; no variation according to the traffic.

Aragon Central Railway Company :

1 111 sleepers (1 788 per mile) and 1 222 sleepers (1 967 per mile) for the 31-kgr. (62.5 lb. per yard) rail.

1 613 sleepers (2 596 per mile) for the 42-5 kgr. (85.7 lb. per yard).

Madrid to Saragossa and Alicante Railways :

1 500 sleepers (2 414 per mile) on straight lines.

1 583 sleepers (2 548 per mile) on curves of 500 to 800 m. (25 to 40 chains) radius.

1 666 sleepers (2 682 per mile) on curves of less than 500 m. (25 chains) radius.

North of Spain Railway :

1 641 sleepers (2 641 per mile) with 31-kgr. (62.5 lb. per yard) rail.

1 620 sleepers (2 607 per mile) with 42.5-kgr. (85.7 lb. per yard) rail.

Finnish State Railways :

1 500 sleepers (2 414 per mile) with 30, 33 and 43-kgr. (60.5, 66.5 and 86.7 lb. per yard) rail.

1 667 sleepers (2 683 per mile) with 25-kgr. (50.4 lb. per yard) rail.

1 778 sleepers (2 861 per mile) with 22-kgr. (44.3 lb. per yard) rail.

French State Railways :

1 500, 1 611, or 1 722 sleepers (2 414, 2 593, or 2 771 per mile) according to the importance of the line, i. e. to the density of the traffic.

Alsace-Lorraine Railways :

1 300 sleepers (2 092 per mile) on secondary lines.

1 300 to 1 600 sleepers (2 092 to 2 575 per mile) for 38 and 41-kgr. (76.6 and 82.6 lb. per yard) rails, on main lines with light traffic.

1 500 to 1 670 sleepers (2 414 to 2 688 per mile) for 46-kgr. (92.7 lb. per yard) rails, on main lines with heavy traffic.

Paris Girdle Railway :

1 500 sleepers (2 414 per mile) and exceptionally.

1 800 sleepers (2 897 per mile) in cuttings of doubtful stability.

French Est Railway :

1 500 sleepers (2 414 per mile) for the 36-kgr. (72.6 lb. per yard) rail.

1 500, 1 666, and 1 777 sleepers (2 414, 2 682, and 2 860 per mile) for the 46-kgr. (92.7 lb. per yard) rail according to the density of the traffic.

1 830 sleepers (2 945 per mile) for the 46 and 55-kgr. (92.7 and 110.9 lb. per yard) rails in tunnels.

This spacing is increased on curves of a radius of less than 500 m. (25 chains).

Midi Railway (France) :

1 091 to 1 454 sleepers (1 756 to 2 340 per mile) for the 38-kgr. (76.6 lb. per yard) rail.

1 364 to 1 545 sleepers (2 195 to 2 486 per mile) for the 44-kgr. (88.7 lb. per yard) rail.

The number of sleepers is varied according to the traffic and the numbers above are increased if need be.

French Nord Railway :

1 625 sleepers (2 615 per mile) for the 30-kgr. (60.5 lb. per yard) rail.

1 505 sleepers (2 422 per mile) for the 45-kgr. (90.7 lb. per yard) rail.

1 500 to 1 778 sleepers (2 414 to 2 861 per mile) for the 46-kgr. (92.7 lb. per yard) rail.

The number of sleepers is varied according to the importance of the traffic and in addition with regard to the nature of the formation.

Paris-Orleans Railway :

1 630 sleepers (2 623 per mile) is standard no matter the density of the traffic.

Paris, Lyons & Mediterranean Railway :

1 500 sleepers (2 414 per mile) for ordinary lines.

1 611 sleepers (2 593 per mile) in heavy traffic and high speed lines.

1 722 sleepers (2 771 per mile) for the Paris to Vintimille trunk line and for lines laid on unstable formation.

Société des Transports en commun de la région parisienne (France) :

770 supports (1 239 per mile) in the case of lines laid on the roadway.

1 277 sleepers (2 055 per mile) in the case of lines laid alongside roads.

The Algerian State Lines :

1 429 sleepers (2 300 per mile) with 28-kgr. (56.4 lb. per yard) rails.

1 300 to 1 400 sleepers (2 092 to 2 253 per mile) with 42-kgr. (84.7 lb. per yard) rail.

1 411 sleepers (2 271 per mile) with 46-kgr. (92.7 lb. per yard) rail.

Have not up to the present varied the sleepers with the traffic but are considering so doing on a line with very heavy traffic.

The Algerian Lines of the Paris, Lyons & Mediterranean Railway Company :

1 333 sleepers (2 145 per mile) but have under consideration the use of 1 500 (2 414 per mile). The number of sleepers is not varied with the traffic.

The Gafsa Railway (Tunis) :

1 200 sleepers (1 931 per mile). Does not alter the sleepering with the traffic.

The Company operating the Tunisian Railways :

1 120 to 1 666 sleepers (1 802 to 2 681 per mile) according to the section of rail, the layout of the line, and the fatigue of the section.

The French West African Colonial Railways :

1 333 sleepers (2 145 per mile) with the 20-kgr (40.3 lb. per yard) rail.

1 250 sleepers (2 012 per mile) with the 25-kgr. (50.4 lb. per yard) rail.

1 500 sleepers (2 414 per mile) with the 26-kgr. (52.4 lb. per yard) rail.

The sleepering is not altered in relation to the traffic.

The French Dahomey Railway Company :

1 285 sleepers (2 068 per mile).

The Damas-Hamah and Extension Railway (Asia Minor) :

1 222 sleepers (1 967 per mile) for the 27.6-kgr. (55.6 lb. per yard) rail.

1 152 to 1 256 sleepers (1 854 to 2 021 per mile) for the 30-kgr. (60.5 lb. per yard) rail.

The sleepering is not changed with the traffic density.

North West of Greece Railway :

1 333 sleepers (2 145 per mile) the number not being varied with the density of traffic.

Italian State Railways :

1 330 sleepers (2 140 per mile) with 36-kgr. (72.6 lb. per yard) rail.

1 420 sleepers (2 285 per mile) with 46-kgr. (92.7 lb. per yard) rail.

1 660 sleepers (2 671 per mile) with 50-kgr. (110.8 lb. per yard) rail.

The number of sleepers varies with the density of traffic and the speed of the trains.

The Lombardy Electric Traction Co. (Italy) :

1 400 sleepers (2 253 per mile).

Guillaume-Luxembourg Railway and Prince Henry Railway and Mining Company (Luxembourg) :

1 416 sleepers (2 279 per mile);

1 444 sleepers (2 324 per mile) and

1 500 sleepers (2 414 per mile) for 46-kgr. (92.7 lb. per yard) rail.

1 333 sleepers (2 145 per mile);

1 444 sleepers (2 324 per mile) and

1 555 sleepers (2 502 per mile) for 38.5-kgr. (77.6 lb. per yard) rail.

Norwegian State Railways :

1 200 sleepers (1 931 per mile) for 25 and 30-kgr. (50.4 and 60.5 lb. per yard) rail.

1 400 sleepers (2 253 per mile) for 35 and 40-kgr. (70.6 and 80.6 per yard) rail.

1 600 sleepers (2 575 per mile) for 49-kgr. (98.8 lb. per yard) rail.

Netherlands State Railway Company and Dutch Railway Company :

1 333 sleepers (2 145 per mile) is standard and exceptionally :

1 666 sleepers (2 682 per mile) for electrified lines with heavy traffic.

Rumanian State Railways :

1 613 sleepers (2 596 per mile); the number of sleepers varies as the maximum axle weight in service.

Serbian State Railways :

1 334 to 1 400 sleepers (2 147 to 2 253 per mile) for 45.25-kgr. (91.2 lb. per yard) rail.

1 267 to 1 400 sleepers (2 039 to 2 253 per mile) for 35.65 kgr. (71.9 per yard) rail.

Swedish State Railways :

The Swedish State Railways use a formula which determines the number of sleepers in terms of the weight of the rails, of the axle weights and of the speed of the train.

Nora-Bergslagen Railway (Sweden) :

1 300 sleepers (2 092 per mile) throughout.

Swiss Federal Railways :

1 450 sleepers (2 233 per mile) formerly, but at the present time :

1 583, 1 600 and 1 612 (2 548, 2 575 and 2 594 per mile) are used.

Czecho-Slovakian State Railways :

1 266, 1 333, 1 399 and 1 466 sleepers (2 037, 2 145, 2 251 and 2 359 per mile) for 44.35-kgr. (89.4 lb. per yard) rail and 11-ton axle loads.

We find that in the case of lines with light traffic 1 300 to 1 670 sleepers (2 092 to 2 688 per mile) are used and that when the traffic is heavy the numbers are 1 400 to 1 780 (2 253 to 2 865 per mile).

Some Companies vary the sleepering with the density of traffic; others according to the nature of the sub-soil or the difficulty of maintaining the track (tunnels, exceptionally frequent train service); and some systematically increase the number of sleepers in curves of small radius.

§ 7c) —	*Have you had to alter the sleepering of certain lines without changing the the rails?*	*Has this alteration of the sleepering been followed by an increased number of rail breakages?*	*What precautions have you taken to avoid such breakages?*
Belgian National Railway Company.	Occasionally.	No.	...
Danish State Railways	Yes, at joints.	No.	...
Egyptian State Railways	Yes.	No.	...
Madrid to Saragossa and Alicante Railways.	No.	...	...
North of Spain Railways . . .	Yes.	No.	...
Finnish State Railways	Yes.	No, not as a rule.	...
French State Railways	Yes.	Occasionally.	When this is done, the rails with the foot too deeply indented into the sleepers are removed.
Midi Railway (France)	Yes.	No.	
Paris, Lyons & Mediterranean Railway.	Yes.	No.	...
Paris to Orleans Railway . . .	Yes.	No.	...
French Nord Railway	No.	...	...
Paris Girdle Railway	No.	...	...
Alsace-Lorraine Railways . . .	Yes.	No.	...

§ 7c) (*continued*). —	*Have you had to alter the sleepering of certain lines without changing the rails?*	*Has this alteration of the sleepering been followed by an increased number of rail breakages?*	*What precautions have you taken to avoid such breakages?*
French Est Railway	Yes.	No.	The alteration in the sleepering has only been done on lines on which the rails are little worn. When the rails are more worn, the track is consolidated by blocks between the sleepers which are not respaced.
French State Railways in Algeria.	Yes.	No, at least not appreciably.	...
The Algerian Lines of the Paris-Lyons & Mediterranean Railway Company.	Yes.	No.	...
The Gafsa Railway (Tunis) . .	No.	...	...
The Tunisian Railway Company .	Yes.	No.	...
French West African Colonial Railways.	No.	...	...
Dahomey Railway Company . .	No.	...	...
Damas-Hamah & Extension Railway.	No.	...	...
Italian State Railways	Yes.	Yes.	None.
Guillaume-Luxembourg Railways and Prince Henry Railway & Mines Company.	No.	...	...
Norwegian State Railways . . .	No.	...	...
Netherlands State Railway Company and Dutch Railway Company.	Yes.	No.	...
Rumanian State Railways . . .	Yes.	No, just the contrary.	...
Serbian State Railways . . .	Yes.	Yes.	...
Swiss Federal Railways	Yes.	No.	...
Czecho-Slovakian State Railways.	Yes.	No.	...

We find that increasing the number of sleepers has been widely practised and has not resulted in the rails breaking, except in exceptional cases.

It appears to be advisable when this is done to remove rails with the foot indented in line with the old sleepers, and also those much worn.

§ 7d). —	*What depth and what material do you use for ballast with each weight of rail? Give the information for the under layer foundation and for the packing, the depth being measured from the underside of the sleeper.* Under layer.	Packing.	Kind of ballast.	*State the maximum size of ballast you now use, or intend to use.*
Belgian National Railway Company	...	30 cm. (12 inches).	Broken stone, slag, clinker.	6 cm. (2 3/8 inch) ring.
Belgian National Light Railway Company.	...	20 cm. (8 inches).	Ashes, broken stone.	6 cm. (2 3/8 inch) ring.
Bulgarian State Railways	20 cm. (8 inches).	15 cm. (6 inches).	Broken stone.	6 cm. (2 3/8 inch) ring.
Danish State Railways	None. When the ballast is replaced by pebbles, the old cleaned ballast is used again as underlayer, and the packing is reduced to 18 cm. (7 inches).	25 cm. (10 inches) for new lines.	Gravel or broken stone.	...
Egyptian State Railways	...	20 cm. (8 inches).	Basalt, shingle.	6 cm. (2 3/8 inch) ring.
Madrid to Saragossa and Alicante Railways.	...	20 cm. (8 inches).	Broken stone.	6 cm. (2 3/8 inch) ring.
Medina del Campo to Zamora, and Orense to Vigo Railways.	...	20 cm. (8 inches)	Broken stone.	7 cm. (2 3/4 inch) ring.
North of Spain Railways	...	15 to 20 cm. (6 to 8 inches).	Broken stone.	5 to 7 cm. (2 to 2 3/4 inch) ring.
Finnish State Railways	34 cm. (13 3/8 inches).	15 cm. (6 inches) to be raised to 26 cm. (10 1/4 inches).	Sand, gravel.	...
French State Railways	...	20 to 25 cm. (8 to 10 inches).	Broken stone.	9 cm. (3 1/2 inch) ring.
Alsace-Lorraine Railways	Thickness measured from the top of the sleepers.	40 to 50 cm. (16 to 20 inches) for existing track. 55 cm. (22 inches) for new track.	Broken stone or slag; gravel.	5 cm. (2 inch) ring.

§ 7*d*) (*continued*). ——	*What depth and what material do you use for ballast with each weight of rail? Give the information for the under layer foundation and for the packing, the depth being measured from the underside of the sleeper.* Under layer.	Packing.	Kind of ballast.	*State the maximum size of ballast you now use, or intend to use.*
...is Girdle Railway	...	20 cm. (8 inches).	Pebbles.	6 cm. (2 3/8 inch) ring.
...nch Est Railway Company	...	30 to 35 cm. (12 to 14 inches).	Clinker, pebbles.	...
...ili Railway (France)	No under layer.	20 cm. (8 inches) for the old lines.	Broken stone.	65 mm. (2 9/16 inch) ring.
	20 cm. (8 inches).	18 cm. (7 3/32 inches) for the new lines.		
...ench Nord Railway	...	35 cm. (14 inches) on the principal lines.	Clinker, or broken stone.	6 cm. (2 3/8 inch) ring.
		25 cm. (10 inches) on the secondary lines.		
...ris, Lyons & Mediterranean Railway (France).	No under layer	20 cm. (8 inches) for the old lines.	...	6 cm. (2 3/8 inch) ring.
	20 cm. (8 inches).	15 cm. (6 inches) for the new lines.		
...gerian State Railways	No under layer.	18 to 25 cm. (7 3/32 to 10 inches).	Sand, gravel, or broken stone.	6 cm. (2 3/8 inch) ring.
...ris, Lyons & Mediterranean Railway, Algerian Lines.	...	...	Broken stone.	6 cm. (2 3/8 inch) ring.
...e Gafsa Railway (Tunis)	No under layer.	25 cm. (10 inches).	Broken stone.	6 cm. (2 3/8 inch) ring.
...e Tunisian Railway Company . . .	...	35 and 40 cm. (14 to 16 inches) for narrow gauge line. 45 cm. (18 inches) for normal line.	Gravel, or broken stone.	6 or 7 cm. (2 3/8 to 2 3/4 inch) ring.
...ench West African Colonial Railways.	...	35 cm. (14 inches)	Broken stone or gravel.	6 cm. (2 3/8 inch) ring.

§ 7d) (continued).	What depth and what material do you use for ballast with each weight of rail? Give the information for the under layer foundation and for the packing, the depth being measured from the underside of the sleeper.			State the ma[illegible] mum size of [illegible] last you [illegible] use, or intend [illegible] use.
—	Under layer.	Packing.	Kind of ballast.	
Dahomey Railway Company	...	40 cm. (16 inches) above the level of the rails.	Slag, sand or broken stone.	...
Damas-Hamah & Extension Railway .	20 to 25 cm. (8 to 10 inches).	10 cm. (4 inches).	Chalk ballast or basalt.	6 cm. (2 3/8 inc[illegible] ring.
North Western Railway (Greece) . .	No under layer.	20 cm. (8 inches).	Shingle.	5 cm. (2 inc[illegible] ring.
Italian State Railways	30 to 35 cm. (11 13/16 to 13 3/4 inches) when the foundation is clayey.	15 to 18 cm. (6 to 7 3/32 inches) generally; 35 cm. (14 inches) for express lines.	Broken stone.	6 cm. (2 3/8 inc[illegible] ring.
Guillaume-Luxembourg & Prince Henry Railway & Mines.	No under layer.	20 cm. (8 inches).	Broken slag.	6 cm. (2 3/8 inc[illegible] ring.
Norwegian State Railways	20 cm. (8 inches).	20 cm. (8 inches).	Gravel or broken stone.	...
Netherlands State Railway Company and Dutch Railway Company.	...	40 cm. (16 inches) from above the sleepers.	Small gravel.	...
Rumanian State Railways	No under layer.	25 cm. (10 inches).	Gravel, sand or broken stone.	6 cm. (2 3/8 inch[illegible] ring.
Swedish State Railways	No under layer.	25 to 45 cm. (10 to 18 inches).	Gravel.	...
Nora-Bergslagen Railway (Sweden) . .	...	50 cm. (20 inches).	Gravel, broken stone.	...
Swiss Federal Railways	...	25 cm. (10 inches).	Broken stone.	8 cm. (3 1/8 inch[illegible] ring.
Czecho-Slovakian State Railways . . .	...	15 to 20 cm. (6 to 8 inches).	Broken stone.	8 cm. (3 1/8 inch) ring.
Serbian State Railways	No under layer.	15 to 25 cm. (6 to 10 inches).	Broken stone.	Do.

We find that it is unusual for the ballast of the line to include an under layer.

The tickness of this under layer when provided, is from 20 to 25 cm. (8 to 10 inches), and may be increased when the nature of the sub soil is such as to require it.

The thickness of the packing layer is from 15 to 25 cm. (6 to 10 inches) as a rule, although the Italian State Railways increase it to 35 cm. (14 inches) on high speed lines.

The ballast, the nature of which is evidently determined by the sources of supply in each area, is generally broken up to pass a 6 cm. (2 3/8 inch) ring, the size of ring varying however, from 5 to 9 cm. (2 to 3 1/2 inches).

§ 7e). —	*Have you increased the length of rails used in order to reduce the number of joints?*	*What is the longest rail generally used?*	*Have you welded rails together with the same object in view?*	*Have any breakages occurred after welding, in line with or near the welded section?*	*Wat is the maximum length between two non-welded joints you have tried ?*
Belgian National Railway Company.	Yes.	18 m. (59 ft. 5/8 in.).	No.	...	...
Belgian National Light Railway (Company).	Yes.	12 m. (39 ft. 4 1/2 in.) for 23-kgr. (46.4 lb.).	Yes.	...	54 m. (177 ft. 2 in.) and even 72 m. (236 feet) when running alongside road ways.
Bulgarian State Railways . . .	Yes.	15 m. (49 ft. 2 1/2 in.).	No.	...	...
Danish State Railways	Yes.	15 m. (49 ft. 2 1/2 in.).	No.	...	...
Egyptian State Railways . . .	Yes.	12 m. (39 ft. 4 1/2 in.).	No.	...	...
Central of Aragon Railway (Spain).	Yes.	9 m. (29 ft. 6 3/8 in.) for 31-kgr. (62.5 lb.). 12 m. (39 ft. 4 1/2 in.) for 40-42 kgr. (80.6-84.7 lb.)	No.	...	...
Madrid to Saragossa and Alicante Railway.	No.	12 m. (39 ft. 4 1/2 in.).	No.	...	...
Medina del Campo to Zamora and Orense to Vigo Railways.	Yes.	12.40 m. (40 ft. 8 1/4 in.).	...	...	...
North of Spain Railway	Yes.	12 m. (39 ft. 4 1/2 in.).	No.	...	...
Finnish State Railways	No.	12 m. (39 ft. 4 1/2 in.).	No.	...	...

§ 7e) (continued). —	*Have you increased the length of rails used in order to reduce the number of joints?*	*What is the longest rail generally used?*	*Have you welded rails together with the same object in view?*	*Have any breakages occurred after welding, in line with or near the welded section?*	*What is the maximum length between two non-welded joints you have tried?*
French State Railways . . .	Yes.	16.50 m. and 18 m. (54 ft. 1 11/16 in. and 59 ft. 5/8 in.).	No, but a number of trials have been made on service lines.	...	...
Alsace-Lorraine Railways . . .	Yes.	18 m. (59 ft. 5/8 in.).	No.	...	...
Paris Girdle Railway	Yes.	18 m. (59 ft. 5/8 in) on ordinary lines 24 m. (78 ft. 9 in.) on bridges.	No.	...	...
French Est Railway	Yes.	18 m. (59 ft. 5/8 in.) in the open; 24 m. (78 ft. 9 in.) in tunnels.	Yes, in tunnels.	No, the test was started in 1927 only.	48 m. (157 ft. 6 in.); 2 bars of 24 m. (78 ft. 9 in.).
Midi Railway (France)	...	22 m. (72 ft. 2 1/8 in.).	No.	...	...
French Nord Railway	Yes.	24 m. (78 ft. 9 in.).	*a*) Yes. *b*) No.	No.	About 100 m. (328 feet) on a steel bridge.
Paris-Orleans Railway	...	16 m. 50 (54 ft. 1 1/16 in.).	No.	...	...
Paris, Lyons & Mediterranean Railway.	...	12 m. (39 ft. 4 1/2 in.) and 18 m. (59 ft. 5/8 in.).	No.	...	...
Société des Transports en Commun de la Région parisienne (France).	Yes.	18 m. (59 ft. 5/8 in.) for 46-kgr. (92.7 lb. rail); 18.20 m. (59 ft. 8 5/8 in.) for Broca rails.	Yes.	No.	No restriction in the roadway. 198 m. (650 feet) when running alongside roads.
Algerian State Railways . . .	...	12 m. (39 ft. 4 1/2 in.).	No.	...	...

§ 7e) (continued). —	Have you increased the length of rails used in order to reduce the number of joints?	What is the longest rail generally used?	Have you welded rails together with the same object in view?	Have any breakages occurred after welding, in line with or near the welded section?	What is the maximum length between two non-welded joints you have tried?
aris, Lyons & Mediterranean Railway (Algerian Lines).	...	12 m. (39 ft. 4 1/2 in.) and 18 m. (59 ft. 5/8 in.).	No.	...	...
he Gafsa Railway (Tunis) . .	...	10 m. (32 ft. 9 3/4 in.)	No.	...	...
unisian Railway Company . .	Yes.	12 m. (39 ft. 4 1/2 in.).	Yes, but with unsatisfactory results.	Yes, some of them.	12 m. (39 ft. 4 1/2 in.). 2 rails of 6 m. (19 ft. 8 1/4 in.)
'rench West African Colonial Railways.	Yes.	12 m. (39 ft. 4 1/2 in.).	No.	...	...
ahomey Railway Company . .	...	10 m. (32 ft. 9 3/4 in.)	No.	...	...
amas-Hamah & Extension Railway.	...	9 m. (29 ft. 6 3/8 in.) for narrow gauge lines; 9.55 m. (31 ft. 4 in.) for standard gauge.	No.	...	...
North Western Railway (Greece).	...	9 m. (29 ft. 6 3/8 in.).	No.	...	...
Italian State Railways.	Yes.	12 m. (39 ft. 4 1/2 in.) and 18 m. (59 ft. 5/8 in.).	Yes.	Yes, a number; the test was not very large as welding is costly.	18 m. (59 ft. 5/8 in.) (3 rails of 6 m.).
Lombardy Electric Traction Company.	...	15 m. (49 ft. 2 1/2 in.).	Yes.	...	...
Guillaume-Luxembourg & Prince Henry Railway & Mines Company.	Yes.	12 m. (39 ft. 4 1/2 in.) for 38.5-kgr. (76.6 lb. rails); 18 m. (59 ft. 5/8 in.) for 46-kgr. (92.7 lb. rails); 24 m. (78 ft. 9 in.) on bridges.	No.	...	...

§ 7e) (continued). —	*Have you increased the length of rails used in order to reduce the number of joints?*	*What is the longest rail generally used?*	*Have you welded rails together with the same object in view?*	*Have any breakages occurred after welding, in line with or near the welded section?*	*What is the maximum length between two non-welded joints you have tried?*
Norwegian State Railways . . .	Yes.	15 m. (49 ft. 2 1/2 in.)	No.	...	...
Netherlands State Railway Company and Dutch Railway Company.	...	18 m. (59 ft. 5/8 in.).	No, but we are soon going to begin for *a*).	...	...
Rumanian State Railways . . .	Yes.	15 m. (49 ft. 2 1/2 in.).	No, but we are going to try.	...	...
Serbian State Railways	Yes.	15 m. (49 ft. 2 1/2 in.).	Yes for *a*) and *b*).	No.	60 m. (197 feet).
Swedish State Railways	Yes.	15 m. (49 ft. 2 1/2 in.).	No.	...	...
Nora-Bergslagen Railway (Sweden).	Yes.	12 m. (39 ft. 4 1/2 in.).	No.	...	...
Swiss Federal Railways	Yes.	18 m. (59 ft. 5/8 in.).	No, but we are going to begin.	...	...
Czecho-Slovakian State Railways .	Yes.	15 m. (49 ft. (2 1/2 in.). We change to 18 m. (59 ft. 5/8 in.) in 1929.	Yes, for *a*) and for *b*).	No.	90 m. (295 feet).

We find there is a general tendency to increase the length of rails.

The most usual length is 18 m. (59 ft. 5/8 in.). Some railways are using 22 and 24-m. (72 ft. 2 1/8 and 78 ft. 9 in.) rails as standard practice.

Others use 24-m. (78 ft. 9 in.) rails on bridges and underground lines.

Up to the present time only a limited number of tests of welding joints appear to have been made. The results of these tests are encouraging and it would appear that the general use of welding could be recommended :

1. On steel bridges in order to lessen the dynamic effects due to the shocks set up when running over rail joints.

2. To facilitate maintenance in tunnels where the variations of temperatures are much less than in the open, and in yards where the possible deformation of the track under temperature variations is not likely to have any ill effects as regards safety.

3. On the leading in lines, in marshalling yards, in order to improve the braking on the lengths on which slipper brakes are used.

§ 8. — *Have you set up any special organisation, or applied any particular regulations to locate in the tracks defective rails and thereby prevent such defects developing into fractures? Do you use any special equipment for this purpose?*

On the Belgian National Railway Company, the lines are inspected at regular intervals, the rails being hammer rung.

The great French Railway Companies grant rewards of 10 to 50 francs to any employee who discovers and reports either a fracture or a fissuration in a rail other than in the course of relaying, or maintenance work.

In addition they carry out a systematic hammer ringing of the rails at intervals which depend upon the importance of the different sections of the line.

On the French Est Railway, this hammering test takes place monthly on the main lines, and half yearly on the secondary lines. In addition in the tunnels once every six months a complete inspection of all points including taking off the fishplates and cleaning the ends of the rails with wire brushes is carried out: this inspection is also made on the running lines carrying a heavy traffic, but once a year only.

On the French Nord Railway the rails on the main lines are hammer rung specially during the first two months of the year, and once again in the course of maintenance work.

On the Paris, Lyons & Mediterranean Railway, the main lines are inspected four times a year and the other lines twice.

The Gafsa Railway and the Tunisian Railway Company grant rewards to employees discovering broken or fissured rails.

The Italian State Railways grant rewards under the same conditions.

The Rumanian State Railways carry out twice a year by staff specially appointed to do the work, an examination of the lines at the places most liable to damage (old rails or lines carrying heavy traffic).

The Czecho-Slovakian State Railways insist upon a careful supervision of the lines and especially in places where breakages are to be feared through the existence of superficial fissures or damage already noted. A mirror fitted to a metal shaft is used to examine parts of the rails not directly visible.

Premiums are paid to the staff reporting broken rails, or rails dangerously damaged.

The other Railway Administrations are satisfied with the inspection of the rails carried out during maintenance work.

We find that some Railways in their instructions relating to the maintenance and inspection of the track, require special steps to be taken with a view to locating broken and damaged rails.

It appears desirable to recommend that the rails on important lines should be hammer rung at least once a year, this period possibly being shortened when the traffic is particularly heavy, or at places where the lines are highly stressed (tunnels, etc.).

No special equipment is used for this hammer test: a small hand hammer (issued by the great French Railway Companies and a mirror (used by the Czecho-Slovakian State Railways) satisfactorily meet the requirements of the usual examination of the rails.

The award of premiums to members of the staff who discover broken or defective rails is to be recommended.

§ 9. — *Have you taken any special steps to improve the counterbalancing of your locomotives and the condition of all tyres? What is the maximum size of flats, measured on the diameter of the wheel, on the tread of the tyre occurring in service, you allow?*

The Danish State Railways balance if possible the whole of the rotating masses of the locomotives and from 15 to 60 percent of the reciprocating parts. In new locomotives the centrifugal force acting on each wheel at the maximum speed allowed must not exceed 15 % of the static load of the wheel.

The Italian State Railways and the Swiss Federal Railways balance their locomotives on the following principle : the parts of steam locomotives in motion are only counterbalanced by the addition of counterbalance weights to the extent in which the centrifugal force of this counterbalance weight does not exceed 15 % of the weight of the axle at rest.

The French Nord Railway and the French Est Railway balance the whole of whole of the rotating parts and as much as possible of the reciprocating parts in such a manner that the vertical reactions do not exceed 75 to 80 % of the unsprung weight of each axle.

These different Railways point out that the question of balancing is completely solved in modern 4-cylinder compound locomotives.

The other Railways have not reported the rules used in counterbalancing their locomotives.

As regards allowable size in service of flats on the tyre treads, most Railway Administrations state as maximum the figure of 5 mm. (13/64 inch) which is considered in the regulation of the « Unité Technique » as the permissible limit for the exchange of carriages and wagons in international traffic.

This limit is fixed at the lower figure of 3 mm. (1/8 inch) on the French Est Railway. The Swiss Federal Railways fix the limit as 5 mm. (13/64 inch) for goods, and 3 mm. (1/8 inch) for passenger vehicles.

The Czecho-Slovakian State Railways fix the limit at 3 mm. (1/8 inch) for all tyres irrespective of size.

The Norwegian State Railways allow on wagons flats up to 60 mm. (2 23/64 inches) in length and 1 mm. (3/64 inch) in depth, but do not go to these limits in the case of locomotive wheels.

The other Administrations report that on their lines the tyres are re-turned when found necessary in service.

We find that on some Railways, the Locomotive Department has taken steps to improve the counterbalancing of the locomotives. It should be noted however, that this question has lost much of its importance with the general use on modern locomotives of more than two cylinders.

As regards the limits allowed for flats on tyres, it would seem desirable not to exceed for either carriages or waggons a maximum depth of 3 mm. (1/8 inch) the figure shown for interchange stock in the new revised prescriptions of the « Unité Technique » now under consideration by the « Union Internationale des Chemins de fer ».

For locomotives this limit of 3 mm. (1/8 inch) is excessive and the Locomotive Running Department should re-turn tyres as soon as they show any signs of flat spot.

B. — RAIL WEAR.

We find that nearly all the Railways have experienced all the seven forms of wear described in the questionnaire (see tables, pages 2068 to 2071.

The last three forms (corrugated wear, wear through oxidation, and wear through incrustation) appear to be less known than the first four, wear by abrasion of the running surface, wear through the formation of side fins, wear by abrasion of the side of the rail head, and wear through hammering).

We think that some supplementary information drawn from our observations should be given upon :

1. The wear of the lower rail on curves.

A certain number of lower rails on curves of small radius have quickly been rendered unserviceable as the result of the formation of considerable flakes (fig. 33).

In most cases this defect has been ascribed to the presence of blow holes and inclusions on the periphery of the rail head (fig. 34) : the flashes were generally accompanied by the running surface of the head of the rail splitting and flaking away.

This defect has however also been found on rails not showing any macrograph defect (fig. 35) and a thorough investigation of the rails in question revealed nothing more than microscopic inclusions which are to be found in many rails free from the defect in question.

The investigation into these rails is being continued in order to define the chemical and mechanical characteristics to be specified in order to obtain rails resisting this form of wear.

2. Corrugated wear.

This form of wear which particularly affects the light railways and tramways, shows itself in two different forms each having one common feature : the production by passing trains of a characteristic high pitched rumble.

In the first form, the rail shows on the running surface dark patches, oval in shape, regularly spaced several centimetres apart (fig. 36). At each of these patches there is a corresponding depression about 2/10th of a mm. (0.0079 inch) in depth. These patches are not found at the ends of the rails on a length of about 40 cm. (16 inches) on each side of the joint.

Research work carried out to ascertain the origin of these depressions showed that they may be attributed to the rollers of the cold straightening machine when the machine is worn in certain ways.

Examined in a straightening machine, the rails pass with the head upwards between five vertical rollers, the three upper driven by the motor, and the two lower are adjustable.

The three upper rollers are keyed to three shafts driven from the motor through gearing so arranged that each shaft has the same angular speed.

If these rollers are exactly the same diameter their circumferential speed will also be the same and, when the machine is running, the rollers will take the rail to be straightened through it *without slip*.

If on the contrary, one of the three rollers is of different diameter to the others, whether smaller or larger, its circumferential speed will also be different, either slower or faster, and it must when running constantly slip on the rail.

This slip would cause a regular and continuous wear of the running surface

B. — RAIL

B. — RAIL WEAR.	§ 1. — *What forms of*		
	a) *Wear of the running surface by abrasion without lateral fins.*	b) *Wear by the formation of lateral fins which are ground away by the wheels in passing.*	c) *Side wear of the head of the rail on lines laid on curves.*
Belgian National Railway Company .	Yes.	Yes.	Yes.
Belgian National Light Railway Company.	Yes.	No.	Yes.
Bulgarian State Railways	...	...	Yes.
Danish State Railways	Yes.	Yes.	Yes.
Egyptian State Railways	Yes.	Yes.	Yes.
Central of Aragon Railway (Spain).	Yes.	Yes.	Yes.
Madrid to Saragossa and Alicante Railways (Spain).	...	Yes.	Yes.
Medina del Campo to Zamora and Orense to Vigo Railways (Spain).	Yes.	Yes.	Yes.
North of Spain Railways	Yes.	Yes.	Yes.
Finnish State Railways	Yes.	Yes.	Yes.
French State Railways	Yes	Yes.	Yes.
Alsace-Lorraine Railways	Yes.	Yes.	Yes.
Paris Girdle Railway	Yes.	Yes.	Yes.
French Est Railway	Yes, especially in the case of old rails.	Yes.	Yes.
Midi Railway (France)	Yes, where the brakes are used.	Yes.	Yes, especially on sharp curves.
French Nord Railway	Yes.	Yes.	Yes.
Paris-Orleans Railway	Yes.	Yes.	Yes, especially on sharp curves.
Paris, Lyons & Mediterranean Railway.	Yes.	Yes.	Yes.
Société des Transports en commun de la région parisienne (France).	Yes.	Yes.	Yes.

AR.

wear have you observed?			
Wear by hammering the joints and in gaps in points and ossings.	e) *Corrugated wear.*	f) *Rusting.*	g) *Wear of the rail foot through incrustation in the rail sleepers, bearing plates, etc.*
Yes.	Yes, but rarely.	Yes, in tunnels and near certain works.	Yes.
Yes.	No, not appreciably.	Yes, especially on the rail foot (slag).	Yes.
...	...	Yes, especially on underground lines where they last a bare twelve years.	...
Yes.	Yes.	Yes.	Yes.
Yes.	No.	Yes, especially near the sea.	Yes.
...	...	...	...
...	...	...	...
...	...	Yes.	...
...	...	...	...
Yes.	Yes.	Yes.	Yes.
Yes.	Yes.	Yes.	Yes.
Yes.	Yes.	Yes.	Yes.
Yes.	Yes, on a hard bed.	Yes, especially in tunnels.	Yes.
especially on rails recent manufacture.	Yes, but rarely.	Yes, especially in tunnels.	Yes.
Yes.	Yes.	Yes, especially in tunnels.	Yes.
Yes.	Yes, but rarely.	Yes.	Yes.
Yes.	Yes, but very exceptionally.	Yes, in some wet tunnels.	Yes.
Yes.	Yes.	Yes.	Yes.
Yes.	Yes.	No.	No.

B. — RAIL WEAR. (Continued.)	§ 1. — What forms		
	a) Wear of the running surface by abrasion without lateral fins.	b) Wear by the formation of lateral fins which are ground away by the wheels in passing.	c) Side wear of head of the rail lines laid on curv
Algerian State Railways	Yes, but little.	Oui.	Yes.
Paris, Lyons and Mediterranean Railways (Algerian Lines).	Yes, but little.	Yes, but little.	Yes, but little.
Gafsa Railway (Tunis)	Yes, 1 mm. (0.039 inch) per 100 000 trains.	Yes.	Yes, when the sup elevation is insuf cient.
Tunisian Railway Company	Yes.	Yes.	Yes, especially sharp curves.
French West African Colonial Railways.	Yes.	Yes.	Yes.
French Dahomey Railway Company (Africa).	Yes.	No.	Yes.
Damas-Hamah and Extensions Railway.	Yes.	Yes.	Yes.
North Western Railway (Greece) . .	...	...	...
Italian State Railways	Yes in the case of hard rails.	Yes, in soft rails.	Yes, we have widen the track and creased the sup elevation.
Lombardy Electric Traction Co. (Italy).	Yes.	Yes.	Yes.
Guillaume-Luxembourg Railways and Prince Henry Railway and Mines Company (Luxembourg).	Yes.	Yes.	Yes.
Norwegian State Railways	...	...	Yes.
Rumanian State Railways	Yes.	Yes.	Yes.
Swedish State Railways	Yes.	Yes, but rarely.	Yes, a great deal
Nora-Bergslagen Railway (Sweden).	Yes.	Yes.	Yes.
Swiss Federal Railways	...	...	Yes.
Rhætian Railways (Switzerland) . .	Yes.	...	Yes.
Czecho-Slovakian State Railways . .	Yes.	Yes.	Yes.
Serbian State Railways	Yes.	Yes.	Yes.

wear have you observed :			
ear by hammering the joints and in e gaps in points and ossings.	e) *Corrugated wear.*	f) *Rusting.*	g) *Wear of the rail foot through incrustation in the rail sleepers, bearing plates, etc.*
but little as a rule.	Yes, but little as a rule.	Yes, but little as a rule.	Yes, but little as a rule.
Yes, but little.	Yes, but little.	Yes, but little.	Yes, but little.
Yes.	Yes, on long down gradients.	Yes, near the sea.	Yes.
Yes.	Yes, but rarely.	Yes, near the sea.	Yes, but rarely.
Yes.	...	Yes, where wagons of salt stand.	Yes.
No.	Yes, on long down gradients.	Yes, near the sea.	Nc.
Yes.	Yes.	Yes.	Yes.
...	...	Yes.	Yes.
Yes.	Yes, especially in wet tunnels on a gradient.	Yes, especially in tunnels.	Yes.
Yes.	Yes, but little.	...	No.
Yes.	Yes.	Yes.	Yes.
Yes.	...	Yes.	...
Yes.	Yes.	Yes.	Yes.
Yes, a great deal.	Yes, but little.	Yes, but little except in tunnels.	Yes, but rarely.
Yes.	No.	No.	No, not appreciably.
...	...	...	...
Yes, at the joints.	Yes, in wet tunnels.	Yes, especially in tunnels.	Yes, but rarely.
Yes.	Yes.	Yes.	Yes.
Yes.	Yes.	Yes.	Yes.

Fig. 33. — Lower rail of line on curve, showing marked fins.

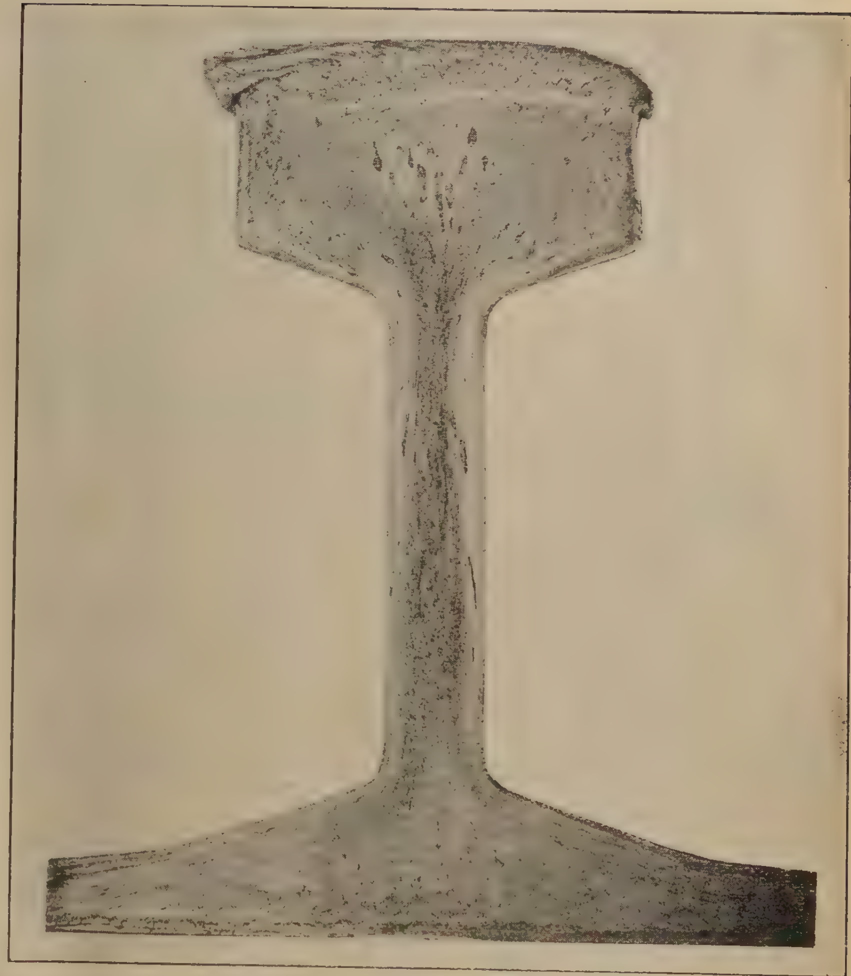


Fig. 34. — Rail showing spreading accompanied by splits and breaking away of the running surface of the head of the rail.

Fig. 35. — Rail with spreading, but in which the macrograph does not show any important defect.

of the rail if there were no play in the gears.

If however, there is any discontinuity of motion in the train of gears due to wear in the gears, the wear through slip will also be irregular and cause depressions the spacing between which on the rails will be a function of the pitch of the gears.

In the straightening machine in question, the diameter of the roller was 525 mm. and driving gears had 30 teeth : the slip of the roller on the rail should therefore repeat at intervals of

$$\frac{\pi \times 525}{30} = 55 \text{ m/m} \quad (2\frac{11}{64} \text{ inches})$$

which was exactly the spacing measured between two adjacent dark patches on the rail which had been straightened in this particular machine.

The same examination was made on rails which had been straightened

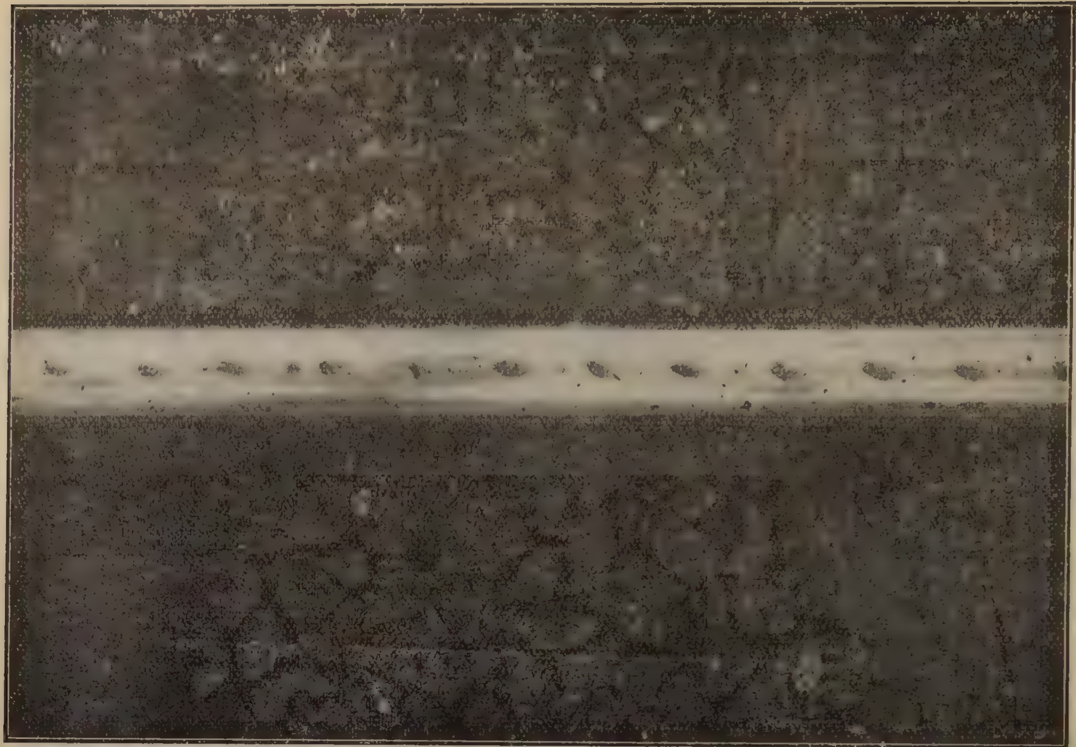


Fig. 36. — Rail showing corrugated wear (1st form).

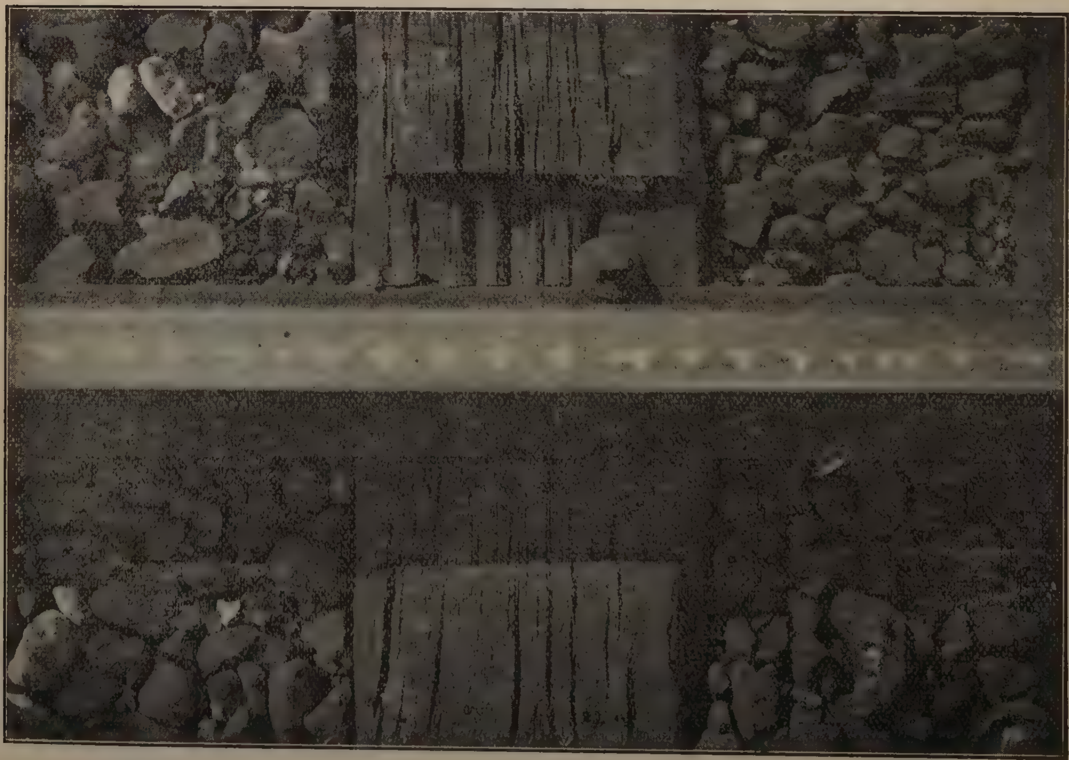


Fig. 37. — Rail showing corrugated wear (2nd form).

through another set of rolls of different design from that mentioned above, the calculations for which showed that the difference apart of the impressions produced on the rails, would be 70 mm. (2 3/4 inches) definitely different from the preceding figure of 55 mm. (2 11/64 inches). An inspection of the rails showed that the depressions on them were in fact regularly spaced 70 mm. (2 3/4 inches) apart.

The ends of the rails do not show any impressions because the rollers do not act on them.

There appears to be no doubt but that the formation of the marks in question is to be ascribed to wear of the straightening machine.

In the second form, the corrugated wear characterised not as in the preceeding case by dark patches in the middle of polished areas, but the opposite, by bright patches in the middle of dull zones, the metal of these patches evidently standing up 1 or 2 tenths of a mm. (0.00395 to 0.0079 inch) above the rest of the running surface of the rails (fig. 37).

The second form of wear cannot be explained by defects in the straightening rolls, as this form of wear was known in France before such machines were brought into use in French steel works. The marks are not so regularly spaced as in the previous case, and are to be found right to the end of the rails.

It has been observed firstly that this second form of wear persists with more or less the same appearance no matter where the rails are used, and secondly, that rails not showing this form of wear continue to be free from it when laid in the line at places where such wear had previously occurred.

In order to set up this kind of wear certain conditions of use of the rails are undoubtedly needed but this form of wear appears to be more especially due to certain sorts of rails or the result of certain manufacturing methods.

Investigations are still being carried out as regards the rail, to ascertain the origin of this particular form of wear.

§ 2. — *How do you measure the wear of rails, and what instruments do you use?*

Do you keep statistics of rail wear? If so state what statistics are kept and give the results.

The Belgian National Railway Company uses profile gauges to measure wear, some of them fitted with an adjusting screw graduated in millimetres.

The Bulgarian State Railways use the Robel instrument.

The North of Spain Railway uses gauges with graduated wedges and also the Macco instrument.

The French State Railways use beam caliper squares with long arms.

The Alsace-Lorraine Railways use the Zimmermann and Buchlot instrument which can only be used for a given profile or one very near to it.

The Paris Girdle Railway uses a profile gauge fitting over the rail with a graduated wedge.

The same method is used by the French Midi and French Nord Railways State Algerian Lines, the Netherlands Railway Company, the Dutch Railway Company and the Rhætian Railway (Switzerland).

The French Est Railway uses a beam caliper gauge when taking readings from rails in service.

In the spare material yards, an instrument with a micrometric screw giving the height of the running surface in relation to the joint is employed.

The French Nord Railway uses, when

taking special measurements requiring greater accuracy, an instrument with sliding pointers fitted with vernier reading to 1/100th of a mm. (0.000395 inch) by means of which a sufficient number of points can be recorded to allow the exact form of the rail head to be drawn down.

The Paris, Lyons & Mediterranean uses compasses, set squares, and various gauges as is the case on the Company's Algerian lines, and on the Tunisian Railways.

The Société des Transports en Commun de la Région Parisienne (France) uses the instrument made by Thornton of Manchester.

The Italian State Railways use the trochytomograph.

The Guillaume-Luxembourg Railways, and the Prince-Henry Railway and Mines Company (Luxembourg) use the Macco instrument.

The Rumanian State Railways use the Wintsen profilograph.

The Swiss Federal Railways use the Shelling profilograph.

The Czecho-Slovakian State Railways use the Fric profilograph and the Vogl instrument, but most often make use of a simple plate gauge with a graduated wedge. To measure lateral wear, they use a Scheblehre rule with movable indicator.

Most of the railways keep no statistics of rail wear.

The Société des Transports en Commun de la Région Parisienne (France) has reported that it has found in practice that, after an initial wear of about 3 mm. (0.118 inch) the wear occurs regularly at the rate of 1 mm. (0.0395) per 10 million tons with rolling stock weighing not more than 9 tons per axle.

We have to report that the wear in height is the only one generally measured. There are a number of devices in use for taking the profile of the rail head in addition to the wear.

We also find that as a general rule, statistics of the vertical and lateral wear are not kept.

This wear il also greater when the rail is first put into service, until the running surface is work hardened by the passage of loaded axles over it. It appears to follow a hyperbolic law, as shown in the graph of (fig. 38).

The side wear is very variable according to the radius of the curves, the superelevation of the track, the nature of the traffic and is also greater when the rails are new.

As an example, we give below, from measurements taken on the French Railways, information of the average number of trains having caused 1 mm² (0.001 square inch) reduction of section on the head of the outer rail on curves.

Radius of curves.	Average number of trains.
500 m. (25 chains).	500
300 m. (15 chains)	250
250 m. (12 1/2 chains.	150

§ 3*a*. — *What steps do you take, when laying rails to reduce wear?*

Are you making the surface of any special form?

— *for rails laid on the straight*

— *for rails laid on curves?*

Negative replies were received to this question from all companies except the Société des Transports en commun de la région parisienne (France), which recommended the use of a rail having a flat running surface in conjunction with cylindrical tyres, and the French Est and Nord Companies who point out that the

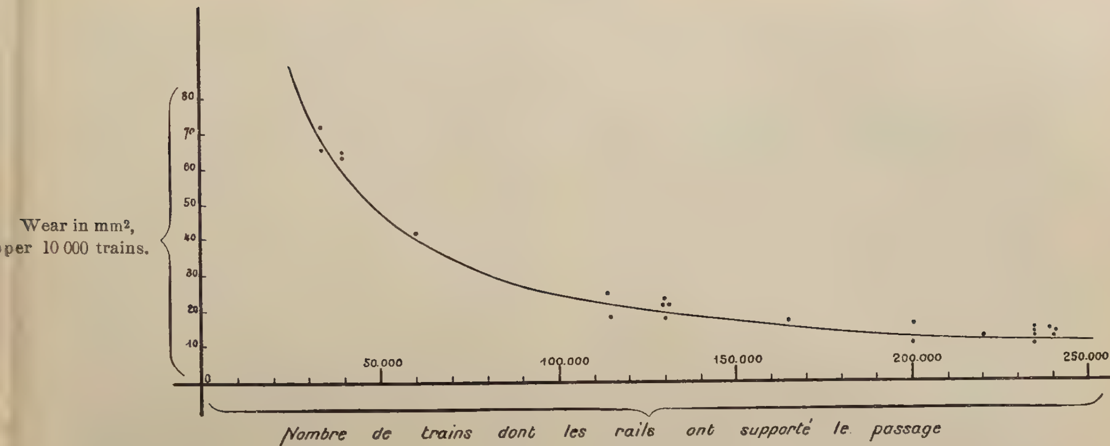


Fig. 38. — Graph showing that the wear in mm² of the cross section produced in rails by the passage of 10 000 trains gradually diminishes as the number of trains which these rails have carried increases.

Explanation of French terms : Nombre de trains ..... = Number of trains borne by the rails.

form of the head of the French Standard rails, was designed to meet the various types of wear of the head of the rail in service.

It would appear, in fact, to be logical to give the running surface of the rail, the shape it tends to assume in service, a shape which has been found to be almost identical on straight sections of line, on the different French Railways.

This enquiry revealed in particular the advantage of rounding the top of the head of the rails and connecting this rounding off with the radius of the side of the head by a curve of intermediate radius.

So far as we are aware, no special section of rail has been used when laying in curves of small radius.

§3*b*. — *Do you use lubricators attached to the rails or to the engines, carriages or wagons in the case of trains running round curves ?*

If so, please give particulars of them.

The Bulgarian State Railways are making tests of lubricating the rails by hand, using mineral oil.

The French State Railways have carried out tests as hereafter :

a) — oiling the side of the rail head by means of a brush wheel which, when at rest, dips into an oil container : the result was poor and at the same time costly.

b) — oiling by hand the rails of such parts of the truck as found to be necessary : the result is unquestionably good.

c) — using on the locomotives the Buclon lubricator which oils the flanges of the wheels (1) : the lubricators have not been long enough is use to be able to give any opinion on the results obtained.

The French Est Railway has recently made tests in a marshalling yard by oiling rails on small radius curves. The

(1) This flange lubricator is described in the *Revue Générale des Chemins de fer* (June 1928). See also *Bulletin of the Railway Congress*, January 1928 number, page 11.

oil is applied by hand every morning and evening with a brush.

The results are not yet available.

The French Midi Railway has tested over a line having curves of 150 m. (7 1/2 chains) radius, a fitting on the locomotives which consists of a tube feeding oil to a bunch of trimmings which distributes it by capillarity to the flanges of the tyres.

The Paris-Orleans Railway is carrying out tests with an arrangement of lubricator which gives satisfactory results and which differs from the preceding in that the lubricator which is fitted to the locomotive oils the side of the rail head on which the engine is running instead of the wheel flanges.

The lubricator consists of :

— a closed container with oil under pressure obtained by means of the compressed air of the brakes;

— a compressed air atomiser, with adjustable feed, breaking up the oil after it leaves the container;

— an automatic control device consisting of a three way cock which is worked by the relative displacement of the bissel truck (or bogie) and of the frame and which directs the oil spray towards the right or left hand rail according to the direction of the curve so as to lubricate the exterior rails on curves. This valve closes and shuts off the oil when the locomotive is running on the straight.

— two pipe lines carrying the oil spray to the right and to the left hand side of the engine : each of these pipe lines ends in a fitting so arranged that only the side face of the rail and not the running surface is lubricated.

With this fitting the rails are lubricated automatically but only at those places on the line, or on the parts of the rails where it is really needed, so that the cost of lubrication is thereby reduced to the minimum.

The Paris, Lyons & Mediterranean Railway has made tests by applying graphite to the rail but have abandoned them as the results were not good enough.

This Railway is now fitting lubricators to the engines which work on its mountain lines.

The Société des Transports en Commun de la Région Parisienne (France) has in some instances lubricated the rails by hand : in the case of lines laid with the Broca rails, good results are obtained by letting water run along the groove in the rails.

The French State Algerian Lines either apply graphite to the rails by hand, or lubricate the locomotive wheel flanges by a fitting on the engine.

The Gafsa Railway (Tunis) graphites the rails by hand and has under consideration the use of fixed lubricators by means of which the lubricant would be picked up by the wheel flanges in passing and distributed over a distance.

The Tunisian Railway Company graphites the rails by hand and has under trial a flange lubricator developed from the Derrick [1] and permanently fixed in track : a displacement lubricator and the Buclon lubricator fitted on the engines are also under trial. The results are most satisfactory : thanks to this lubrication the locomotive tyres should run without re-turning double the mileage obtained before flange lubrication was introduced.

The Damas-Hamah Railway and extensions (Asia Minor) either graphites rails by hand or uses for lubricating the loco-

(1) This device was described in the *Bulletin of the Railway Congress* of August 1927, p. 703.

motive wheel flanges various fittings and in particular the Buclon lubricator.

The Italian State Railway have used different patterns of flange lubricators carried on the engines and have found them very satisfactory.

The Guillaume-Luxembourg Railways, and the Prince Henry Railway and Mining Company (Luxembourg) lubricate the locomotive wheel flanges by means of the Buclon lubricator carried on the locomotives.

The Roumanian State Railways have fitted several locomotives with such lubricators for test purposes, but have given them up as they found them inefficient.

The Swiss Federal Railways have carried out some experiments with lubricators fitted to the locomotives, but so far they have not given the expected results. The tests are being continued : in addition, fixed lubricators on the Derrick system are being tried out.

The Rhætian Railway (Switzerland) has made some trials the results of which have been satisfactory, although the working of the lubricators was not altogether good in very cold weather.

We find that without being a part of their standard practice, the lubrication of the side surfaces in contact, either of the rails, or of the wheels of the engine, to facilitate running through curves of small radius and thereby reduce the wear of the surface in contact, is being carried out by many Companies with satisfactory results.

The lubricators are fitted either permanently in the track, or are carried upon the locomotive. According to information collected by various French Railways, in the latter case all that is needed to obtain satisfactory results is for a few engines alone to run over the line to be fitted with these lubricators : one greasing per 20 trains running through the curve.

No Company has so far given any comparisons as to the economy realised from the reduction of wear of rails and tyres on the one hand, and of the saving in expenditure resulting from lubricating in this way.

The Paris-Orleans Railway estimate that, ignoring the reduction of wear of rails, the lubrication gives on tyres alone, an economy, which can be figured at approximately 0.10 franc plus the power saved, per train-kilometre (0.16 French franc per mile).

It would be of value if definite information of the same kind could be given by other Railways who have carried out lubricating trials.

§ c. — *Do you use check rails on curves of small radius?*

Give particulars and information as to the way they are used.

The Belgian National Railway Company uses check rails on curves of less than 350 m. (17 1/2 chains) radius at places where derailments may have particularly serious consequences : approaches to high viaducts, or a high embankment. These check rails do not prevent the wear of the outer rail, and only come into action in the event of a derailment, in order to lessen the consequences.

The Belgian National Light Railways use check rails on curves of less than 50 m. (2 1/2 chains) radius.

The Egyptian State Railways use checks rails on curves under 150 m. (7 1/2 chains) in radius.

The French State Railways have carried out some experiments as for example at the approach to Passy station but the tests were not altogether satisfactory.

The Alsace-Lorraine Railways use check rails with a 57 mm. (2 1/4 inches) wide flange on curves of a radius of 500 to 325 m. (25 to 16 1/4 chains) and with a 63-mm. (2 3/4 inches) flange when the radius in between 325 and 180 m. (16 1/4 and 9 chains).

The French Est Railway has laid down check rails in some places but have found they interfere with the way the engines take the curves and do not prevent wear of the rails. Their use has consequently been practically given up.

The French Midi Railway has used check rails with a 70-mm. (2 3/4 inches) wide flange, on a length of 230 m. (759 feet) at a point on the line at which the radius is only 150 m. (7 1/2 chains).

The Paris, Lyons & Mediterranean Railway has laid check rails at a number of places.

The Algerian Lines of the Paris, Lyons & Mediterranean Railway uses check rails when the curve is 200 m. (10 chains) or less.

The Italian State Railways only use check rails in a few special cases of which however they have not given any details.

The Netherlands State Railway Company and the Dutch Railway Company use check rails with flanges of 52 to 60 mm. (2 3/64 to 2 23/64 inches) wide on curves of small radius.

The Swiss Federal Railways use check rails but only rarely and the results have moreover not been satisfactory, and some other arrangement is being sought after.

The Czecho-Slovakian State Railways use check rails on industrial sidings, on curves of less than 125 m. (6 1/4 chains) radius; a flange of 55 mm. (2 3/16 inches) when the line is on a curve of 120 m. (6 chains) radius with the gauge of 1.465 m. (4 ft. 9 11/16 in.). On smaller radius curves the width of the flange is increased and may be as much as 70 mm. (2 3/4 inches).

The Société des Transports en Commun de la Région Parisienne (France) and the Lombardy Electric Traction Company (Italy) use check rails on curves but do not state the way in which they are used.

The Bulgarian State. the Danish State, the Madrid to Saragossa and Alicante (Spain), the North of Spain, the Paris Girdle, the French Nord, the Paris-Orleans, the State Railway Lines in Algeria, the Gafsa (Tunis), the Tunisian, the French West African Colonial, the Dahomey (Africa), the Guillaume-Luxembourg and the Prince Henry Railways, the Norwegian State, and the Swedish State Railways, do not use check rails on curves.

We find that few railway companies use check rails on curves of small radius and that some of them have given up their use.

Check rails used in this way do not reduce the wear of rails in the running lines and only serve to lessen the consequences of derailments.

§ 3*d*. — *Do you use, in tunnels or where there is much water, a heavier rail section?*

In what way does this section differ from the standard section?

Do you protect the surface of the rails against oxidation by painting, covering, etc.?

The large French systems and the Paris, Lyons & Mediterranean Company's Algerian Lines use, in tunnels, a heavier rail weighing 55 kgr. per metre (110.8 lb. per yard).

This section (55 kgr.) is a development of the usual rail [(46 kgr. (92.7 lb. per yard)] by increasing the height of the

head (6 mm. = 1/4 inch), the thickness of the web (4 mm. = 5/32 inch) and the thickness of the foot (3.5 mm. = 9/64 inch) with a view to avoiding or rather of delaying the withdrawal of the rail as a result of rusting.

The French State Railways have tried tarring the rails, but these tests were not followed up as the tar hid any fissures there might be in the rails.

The Alsace-Lorraine, the Paris, Lyons & Mediterranean Company's Algerian Lines, and the Tunisian Railways, apply tar to the rails as does the French Est, which has two coats of tar applied hot after rolling, at the works.

The Paris, Lyons & Mediterranean Railway has placed orders for 500 tons of rails of steel with 0.3 % of copper, as copper bearing steel is more resistant to rusting.

The Italian State Railways use in tunnels 50-kgr. (100.8 lb. per yard) rails and have tried protective coatings which, however, they have given up as they gave no good result.

The Norwegian State Railways use in tunnels a heavier section rail, containing 0.2 % of copper : they have not given particulars of this rail.

The Serbian State Railways use in certain tunnels heavier rails than those ordinarily used on the same lines [35.65 kgr. and 47.1 kgr. (71.86 and 94.9 lb. per yard) in place of 26.15 kgr. and 35.65 kgr. (52.71 and 71.86 lb. per yard) respectively]. This System also in some cases tars these rails as a protection against rust.

The Swiss Federal Railways use in tunnels a heavier rail weighing 49 kgr. per m. (98.8 lb. per yard) which is derived from the usual rail by increasing the height of the head (2 mm. = 5/64 inch) and the thickness of the web (2 mm. = 5/64 inch).

The Czecho-Slovakian State Railways use in tunnels a rail weighing 47 kgr. per m. (94.7 lb. per yard) but do not use any protective covering.

We find that with the exception of the French Railways, the Norwegian State Railways, and the Swiss Federal Railways, a heavier rail section is not used on underground lines.

As regards protection of the rails against oxidation by coating them with protective materials, the main French Companies, and the Serbian State Railways, are the only ones doing so (the Italian State Railways have given up the practice after trials which showed that no advantage resulted).

These Companies use for this purpose tar, which for satisfactory results has to be applied hot to the rails as they leave the rolling mill.

The tests of rails of copper bearing steel are interesting, and there would appear to be good reason for extending the trials so that definite conclusions may be drawn as soon as possible.

§ 3e. — *Do you favour the use of metal sole plates interposed between the bottom of Vignoles rails and the hard wood sleepers ?*

The Belgian Light Railway Company considers it desirable to use metal sole plates on curves of less than 200 m. (10 chains) radius.

The Bulgarian State Railways use metal sole plates generally and consider their use advisable even with oak sleepers.

The Medina del Campo to Zamora and Orense to Vigo Railways (Spain) are also in favour of this practice on lines carrying heavy axle loads.

The Danish State, the Egyptian State, the Madrid to Saragossa and Alicante, the North of Spain, the Finnish State, the State lines in Algeria, the Gafsa (Tunis), the Lombardy Electric Traction (Italy), the Rumanian State and the Swiss Federal Railways, have also replied in favour, without making any reserve.

The Alsace-Lorraine Railways are of opinion this practice should be followed on sharp curves.

The French Est Railway does not favour the use of metal sole plates, but uses compressed poplar packings to protect the planed face of the sleepers on which the foot of the rails rests.

The French Midi Railway prescribes the use of sole plates when the ballast is not sandy : if it is, they think these plates should not be used so as to avoid wear of the foot of the rail by indentation.

The Paris, Lyons & Mediterranean Company's Algerian lines and the Tunisian Railways favour the use of sole plates especially on curves.

The Italian State Railways use metal sole plates, but are looking into the matter at the present time to see if their use can be given up.

The Guillaume-Luxembourg Railways and the Prince Henry Railways and Mines, use metal sole plates or poplar packings.

The Netherlands State Railway Company and the Dutch Railway Company prefer the use of poplar packings.

The Serbian State Railways think metal sole plates should be used even when the line is laid on hard wood sleepers. They laid in 1928, however, on one of their main lines 300 km. (186 miles) of track of 45-kgr. (90.7 lb. per yard) rail without sole plates.

The Swedish State Railways, although using sleepers of soft wood (pine), consider it unnecessary to use metal sole plates when the foot of the rails has a good bearing and when the sleepers have ample bearing surface : 5 inches at least.

The Czecho-Slovakian State Railways favour the use of sole plates and use them on all standard gauge lines, with sleepers of all kinds of wood.

We find that a large number of Railways use a metal sole plate between the Vignoles rail and the sleeper.

On some railways, the plate is used on sharp curves only, other railways use these plates because their sleepers are of soft wood.

We think that, provided the bottom of the rail is kept in contact with the levelled off seat on the sleeper by carefully tightening up the fastenings and under present axle loads, the use of metal sole plates on hard wood sleepers even on sharp curves can be dispensed with.

When metal sole plates are used, it is still necessary to keep the fastenings tighly screwed up if wear of the rail foot by indendation at the sole plates is to be avoided.

We find furthermore that a number of Railways use compressed packings of poplar in order to preserve the machined rail seat. The utilty of these packings in also arguable.

§ 4. — *What special characteristics do you consider should be laid down in the specifications as to the metal used for making rails in order to reduce the different types of wear given in paragraph 1 above?*

Have you made laboratory tests to measure and compare the wear of different steels used for rails? What results have you obtained?

In order to reduce the wear of rails to be laid :

a) *on the straight,*

b) *on curves,*

c) *in points and crossings,*

do you use heat treated steels, or high tensile steels, or lastly steels of special composition?

If so give the chemical, physical and mechanical characteristics specified for these steels as well as any special manufacturing and inspection requirements.

What results have you obtained?

The Belgian National Railway Company has given special attention to obtaining rails of sound metal that is not brittle, and has considered the resistance to wear as of less importance : no steps have been taken up to the present to get better wearing qualities. No tests have been made to measure the wear, neither have heat treated rails, high tensile rails, nor rails of special steel been used.

This Company decided in 1928 to obtain all frogs in crossings and slips in 12 to 14 % manganese steel, and to use as a trial for the tongues and stock rails, electric steel rails of 70 to 80-kgr. (44.4 to 50.8 Engl. tons per square inch) tensile with a minimum elastic limit of 40 kgr. (25.4 Engl. tons per square inch) and elongation of 12 %, minimum resilience 3 Kg.-M. (21.7 foot-pounds) drop test with 1 000-kgr. (2 200 lb.) tup falling 6 m. (19 ft. 8 1/4 in.) on a 1.50 m. (4 ft.-11 in.) length of rail on two supports 1.10 m. (3 ft. 7 5/16 in.) apart.

The Bulgarian State Railways are using at the present time a steel of a tensile strength of from 60 to 70 kgr. (38.1 to 44.4 Engl. tons per square inch) but have recently decided to use in future a steel of between 65 and 75 kgr (41.3 and 47.6 Engl. tons per square inch).

For points of crossings, manganese steel will be used in future.

The Madrid to Saragossa and Alicante Railways do not use any special steel except on points and crossings where manganese steel is used.

The Northern of Spain think that in addition to increasing the carbon content from 0.40 to 0.50 or 0.60 % for Bessemer steel and 0.55 or 0.65 % for Martin steel, the manganese content should also be raised. This Railway has tested rails heat treated by the Sandberg process but the results have not been altogether satisfactory.

The Finnish State Railways specify for the steel from which the rails are made, a minimum tensile strength of 70 kgr. per mm^2 and a coefficient $R \times A$ of not less than 900. This system does not use any special steels, but heat treats the rails used in making up crossings.

The French State Railways consider that the tensile strength elongation and elastic limit of the metal used for making rails should be as high as possible : they consider, none the less, that the tensile strength should not exceed 70 kgr. (44.4 Engl. tons per sq. inch).

No laboratory tests have been made to measure and compare the welding qualities of the various steels used for rails : heat treated rails have as an experiment been laid, but too recently for any conclusion to be formed.

The Alsace-Lorraine Railways use both heat treated and special steels.

The Paris Girdle Railway favours high tensile steel. Heat treated rails are used, and both 80-kgr. (50.8 Engl. tons per sq. inch) and manganese steels in points and crossings.

The French Est Railway has not so far in the ordinary manufacture of rails, laid down any special requirements in

order to reduce wear with which they are less concerned than with their brittleness.

Their system has however, tested on running lines heat treated rails: for points and crossings on the main lines the frogs are usually made of manganese steel. Chrome nickel steel is being tested in the same parts.

The French Midi Railway would agree with the use of steels giving as high tensile strength as possible, such as 80-kgr. (50.8 Engl. tons per sq. inch).

This system has had in service for the last ten years on the Bordeaux-Irun line, 70-kgr. (44.4 Engl. tons per sq. inch) Thomas rails, 70-kgr. Martin rails, and 80-kgr. (50.8 Engl. tons per sq. inch) Bessemer rails, but has not yet been able to draw any conclusions from this comparative test.

The French Nord Railway uses heat treated rails at places where locomotives slip frequently, and on curves of small radius.

In points and crossings' work, manganese steel is used for the points of crossings. Nickel chrome steel is being tried for the same details.

Comparative figures of wear (in millimetres of the cross section) after three years service of heat treated and untreated rails laid on a curve of 2 000 m. (100 chains) radius were found to be as follows:

85-kgr. (54.0 Engl. tons per sq. inch)) Martin steel: 40 mm² (0.0620 sq. inch).

72-kgr. (45.7 Engl. tons per sq. inch) Thomas heat treated: 44 mm² (0.0682 sq. inch).

72-kgr. (45.7 Engl. tons per sq. inch) Thomas not treated: 54 mm² (0.0843 sq. inch).

62-kgr. (39.4 Engl. tons per sq. inch) Thomas heat treated: 52 mm² (0.0806 sq. inch).

62-kgr. (39.4 Engl. tons per sq. inch) Thomas not treated: 58 mm² (0.0899 sq. inch).

In order to compare in the laboratory the wear of the different classes of rail steels, this Company makes a test by rolling small diameter (6.35 mm. = 1/4 inch) balls on washer shaped test pieces (fig. 39). The balls which carry a variable

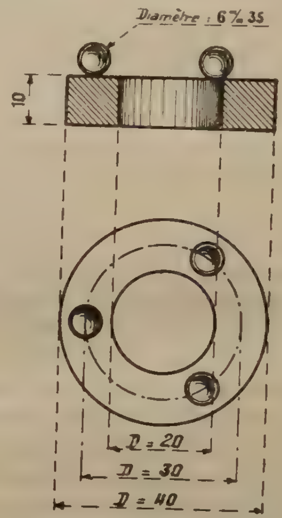


Fig. 39. — French Northern Railway. — Test pieces for wear test by rolling, of the various types of steel used for rails.

weight, marks the test piece with a groove of circular form which deepens as the test is continued. At the end of an hour, a set of three balls carrying 150 kgr. (330 lb.) leaves a groove 0.3 mm. (1/8 inch) deep and 3 mm. (1/8 inch) wide, and the test piece loses in weight between 0.005 to 0.05 grammes (0.077 to 0.77 grains) according to the kind of steel.

The first test carried out with this device showed that there was a certain relationship between the results obtained and the wear found in the track. The tests are being continued in order to define the best experimental condition to

differentiate as regards wear between the different rail steels.

The Paris, Lyons & Mediterranean Rail-heat treated by the Neuves-Maisons and the Sandberg processes.

The Paris-Lyons-Mediterranean Railway agrees that high elastic limit steels should be used for rails. This Company uses heat treated rails by the Neuves-Maisons and Sandberg processes, and for details used in points and crossings, manganese steel.

For the latter purpose, a test is about to be made with nickel chrome steel.

The Société des Transports en Commun de la Région Parisienne (France) are of the opinion that in order to increase the resistance to corrugated wear it is desirable to use steel with a high elastic limit, a high tensile strength giving consequently a high value of the total work at fracture done etc., in conformity with the conclusion of the report made by M. Bacqueyrisse, and published in the review l'*Industrie des Voies ferrées et des Transports automobiles*, December 1927, and of the report given before the Congress of the International Union of Tramways, of Light Railways, and of Public Automobile Transport, held in Rome in May 1928.

This Company has made tests of wear using the Amsler machine.

It uses steels heat treated by both the Neuves-Maisons and Sandberg processes, manganese steel and nickel chrome steel.

The Italian State Railways consider that steel with a tensile strength of between 72 and 85 kgr. (45.7 and 54.00 Engl. tons per sq. inch) should be used.

This system has under observation rails containing 1.8 % of manganese and 0.4 % of carbon and others containing 0.4 % of silicon; it has also made tests of rails containing 0.6 % of copper.

The laboratory of this system has carried out investigations on the wear of rails using Amsler and Rockwell machines, and will publish the results of the tests when they are finished.

The Rumanian State Railways consider it desirable to limit the elongation obtained when carrying out tensile tests to 15 % to require a tensile strength exceeding 72 kgr (45.7 Engl. tons per sq. inch) and an elastic limit of about 40 kgr. (25.4 Engl. tons sq. inch). They consider a high silicon steel should be asked for.

This system has not carried out any wear tests, but has pointed out that Thomas steel having a tensile strength above 75 kgr. (47.6 Engl. tons per sq. inch) is not entirely satisfactory for rails. In points and crossings' work rails of steel with a minimum tensile strength of 80 kgr. (50.8 Engl. tons per sq. inch) with an elongation of over 8 % and parts in high manganese steel with a tensile strength of as much as 112 kgr. (71.7 Engl. tons per sq. inch) with 12 % elongation are used; the results obtained have been very good; after six years service only an insignificant amount of wear has been observed.

The Swedish State Railways consider that very hard high tensile steel with a fairly high manganese content should be used.

The Swiss Federal Railways have observed that the steel rails delivered since 1910 wear much quicker than those which were supplied previously and specially than those that were supplied prior to 1900. This has led them to take in hand laboratory tests which are still going on although without any conclusive results so far.

As from the beginning of 1928 this system specifies a minimum tensile strength of 70 kgr. (44.4 Engl. tons per sq. inch), a resilience of approximately

2 Kg.-M. per square centimetre (93.2 foot-pounds per square inch), a sulphur content less than 0.05 %, a phosphorus content less than 0.08 %, a carbon content less than 0.45 %, a manganese content greater than 1.05 % and a silicon content less than 0.15 %.

This system has in hand tests of rails containing 1.6 % of manganese, and others with 0.35 % of silicon.

The Czecho-Slovakian State Railways have not carried out so far, any comparative tests on the wear of the different qualities of rail steels. They do not use, moreover, any heat treated rails, any high tensile rails, nor any rails of special composition.

We find that Railway Companies appear to be little perturbed by the wear of rails *on the running lines*, as they consider it is of first importance to have rails that are not brittle.

The majority of them specify a quality of steel with a tensile strength equal or superior to 70 kgr. (44.4 Engl. tons per sq. inch).

The majority require a minimum elongation, related to the resistance of rupture by a formula of the form

$$R + KA \geqslant M.$$

The Rumanian State Railways however think that care should be taken to set aside rails with very high elongation ($<$ 15 %) as such rails spread more than the others.

As a rule the specifications do not contain any clause on the subject of the elastic limit, but the tendency is to require a minimum elastic limit [40 kgr. $\geqslant$ (25.4 Engl. tons per sq. inch)].

Some railways specify the use of steel with a high manganese content (1 to 1.8 %), but do not give any results obtained as regards wear with rails statisfying the requirements as to analysis.

A number of Railway Companies have laid test sections of track for comparative purposes, in order to learn the resistance to wear of the different qualities of steel (Thomas, Martin, Bessemer), but have not been able so far to come to any conclusions from the results of the tests. The same may be said of the laboratory tests.

Briefly, no Railway Company ascribes the resistance to wear of the rails to a chemical, physical or mechanical property of the steel, capable of being brought out by the ordinary tests in the laboratories. The general tendency is to take harder rails in order to increase the resistance to wear.

On curves of smaller radius the railways appear to use only ordinary rails; a number however are carrying out tests of heat treated rails in order to reduce as much as possible the wear of the higher rails as well as the crushing of the lower.

In points and crossings, the tendency is to use rails of harder quality [R $\geqslant$ 80 kgr. (50.8 Engl. tons per sq. inch)] and especially to make the nose in cast manganese steel and in nickel chrome steel.

The Société des Transports en commun de la Région parisienne (France) uses on curves of very small radius rails made from 12 % manganese steel or from nickel chrome steel.

After a special investigation into the corrugated wear which is so destructive to the rolling stock this Company requires in order to prevent the formation of this wear, the use of steel giving as large a diagram under tension as possible. It specifies, in its specifications, the conditions $R \times A \geqslant 1050$.

According to tests which this Society

has carried out heat treated rails having the rolling surface with a sorbitic texture also show corrugated wear; on the other hand it appears that this form of wear does not occur on rails when the running surface is of a martensitic texture.

If this opinion should be confirmed we should therefore have as a result of a heat treatment carried far enough to give a martensitic texture, a method of avoiding corrugated wear and of reducing to a large extent all other forms of wear on rails when laid in such a manner that they do not undergo any bending or excessive shocks, that is to say whenever such rails can without danger have a sertain brittleness.

C. — RAIL JOINTS

§ 1. — *Do you keep any statistics of the life of joints in service, of fractures and defects in fishplates? If so, indicate upon what data the statistics are based, and give the results.*

The French Est Railway does not keep regularly any statistics but is able to state, none the less, that the percentage of broken fishplates per annum is on the average 0.8 % of the total number of fishplates in service.

The French Nord Railway, has formed test sections fitted with different types of fishplates in order to be able to compare the number of broken fishplates. These tests are too recent for any conclusions to be drawn therefrom.

The Rhætian Railways (Switzerland) have about 350 broken fishplates per annum on 277 km. (172 miles) of line.

We find that as a rule statistics are not kept as to the number of broken fishplates. We think that it would be of great value if such statistics were kept, not only in order to be able to obtain an average figure applicable to the whole of the Railway System which could be compared with similar figures of other Railways, but also to be able to draw up as regards any one Railway, a comparison between different types of fishplates or of fishplates made from different materials.

§ 2. — *Have you made any tests since 1925 with new types of joints?*

If so describe the tests, and state the results obtained.

The Belgian National Railway Company carried out in 1927 experiments with joints having the sleepers touching although not fastened together.

It appears that the results with this type of joint will be satisfactory, but the test is of too recent date for any final opinion to be formed at present.

The Danish State Railways introduced in 1925 for 37-kgr. (74.6 lb. per yard) rails, the type of joint employed since 1913 for 45-kgr. (90.7 lb. per yard) rails (supporting sleepers bolted together).

The Finnish State Railways are using with success joints in which the two sleepers brought together until they are almost in contact, are bolted together by means of horizontal bolts and wooden packings forming stays.

The French State, and Alsace-Lorraine Railways use a design of joint the sleepers of which are closed together to 280-mm. (11 1/32-inch) centres, without being secured together (fig. 40). The results are satisfactory.

The Paris Girdle Railway has made tests with the Levaire joint (fig. 41) which has given under conditions of maximum stress entirely satisfactory results. With this type of joint it is not necessary to drill the end of the rails.

The French Midi Railway has been

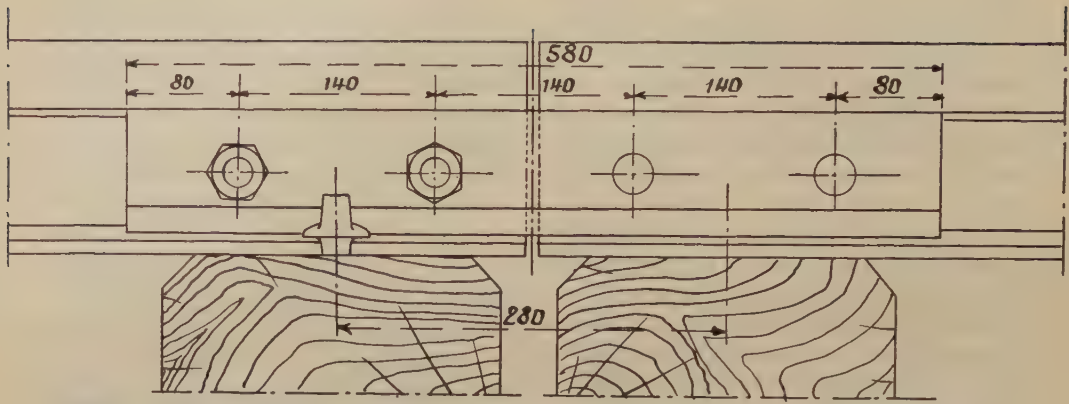


Fig. 40. — French State Railways. — Joints with sleepers brought close together without touching, for 46-kgr. (92.7 lb. per yard) rails.

testing since 1926 a new type of fishplate known as the chevron fishplate, the description of which has been given in the *Bulletin of the Railway Congress Association* of October 1927. About one hundred kilometres of their main line are now fitted in this way.

This joint (fig. 42) uses short fishplates 210 mm. (8 1/4 inches) long which bear at their middle under the upper bearing fishplate surfaces of the rail and at their end on the lower bearing. These fishplates are held in place by two bolts only, the bolts being fitted with a spring washer to prevent the nut from slacking back.

The French Northern has standardised the use of a joint with a sole plate with a wood distance piece (fig. 43); this design is found to be quite satisfactory.

This Company has also made tests with the Levaire joint and the chevron fishplate (see above).

The tests are of too recent date for any conclusions to be drawn from them.

The French Est, Paris-Orleans, Paris, Lyons & Mediterranean, and the Gafsa Railway (Tunis) also use with success the same type of joint, with the joint sleepers close together as that used by the French State Railways.

The French Est Railway is also making experiments with the Levaire joint, the chevron fishplate joint and the joint with sole plate and wood packing piece.

The Italian State Railways are using with the 36-kgr. (72.6 lb. per yard) rail, bridge joints (fig. 44) and are about to use the same arrangement for 46 and 50-kgr. (92.7 and 100.8 lb. per yard) rails.

The Netherlands State Railway Company and the Dutch Railway Company have definitely adopted the supported joints described in the April 1925 number, first part, of the *Bulletin of the Railway Congress* (Report No. 4, by Mr. Willem on question II : Fractures of rails. — Joints).

The Rumanian State Railways have carried out experiments since 1925 with twin joint sleepers bolted together, and this arrangement has given excellent results.

The Serbian State Railways have adopted since 1928, for lines having 45-kgr. (90.7 lb. per yard) rails, a joint with twin joint sleepers assembled together by bolts;

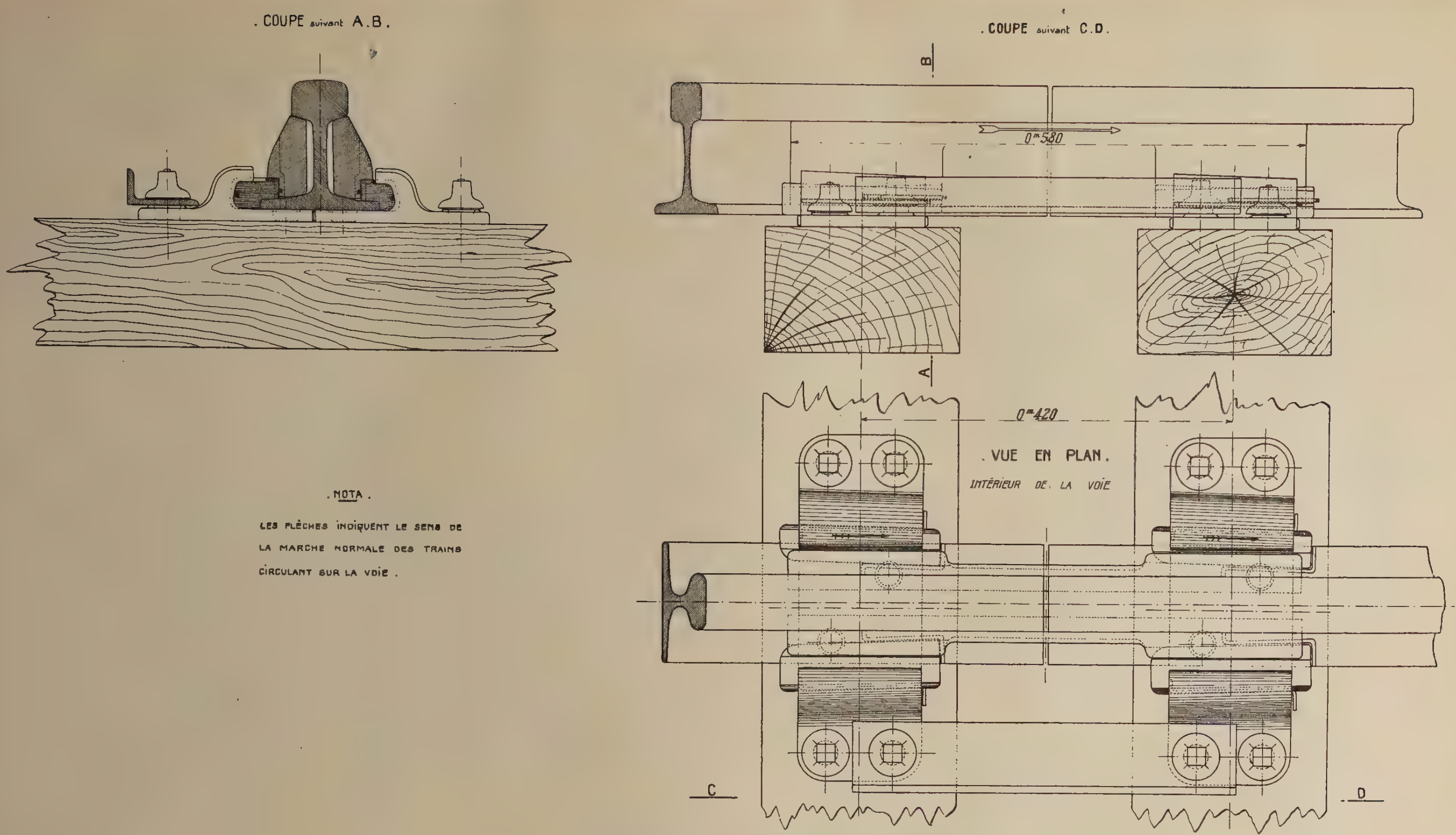


Fig. 41. — Paris Girdle Railway. — Levaire joint.

Explanation of French terms : Coupe suivant... = Section on... — Vue en plan. Intérieur de la voie = Plan view, inside of the track. — *Nota*. Les flèches indiquent... = *Note*. The arrows show the normal direction in which the trains run.

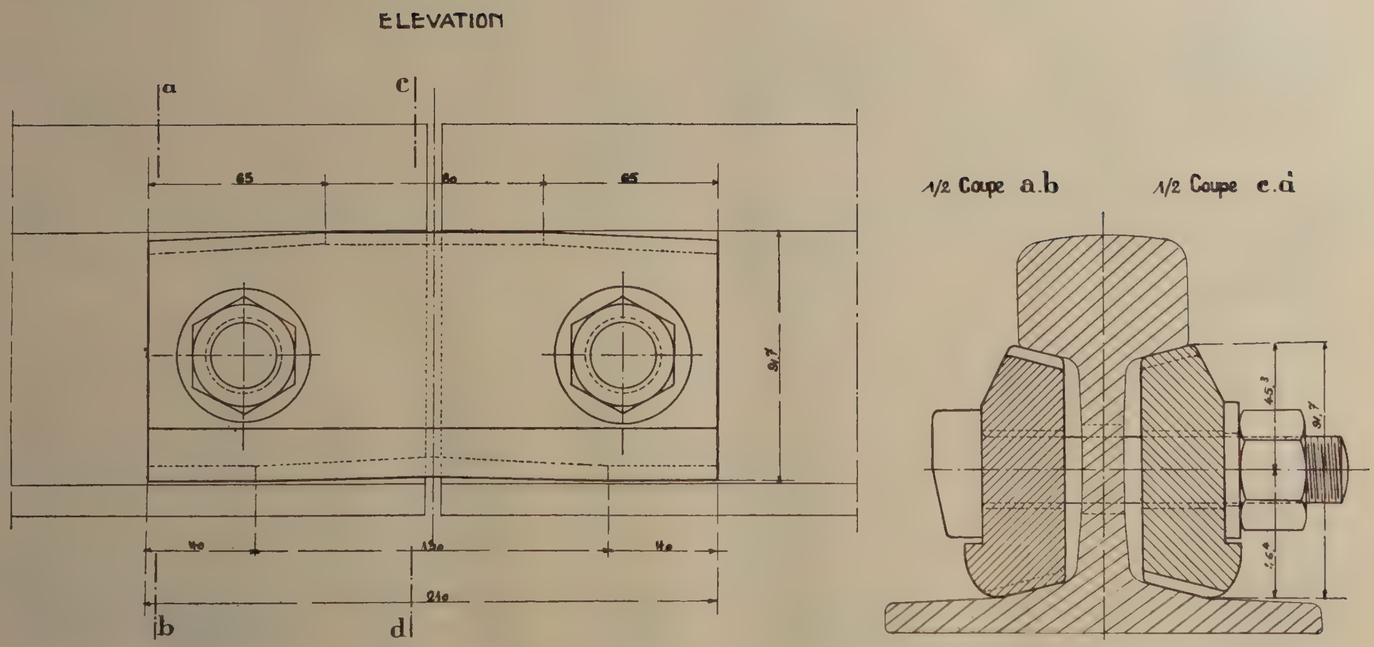


Fig. 42. — Midi and other French Railways. — Chevron fishplate.

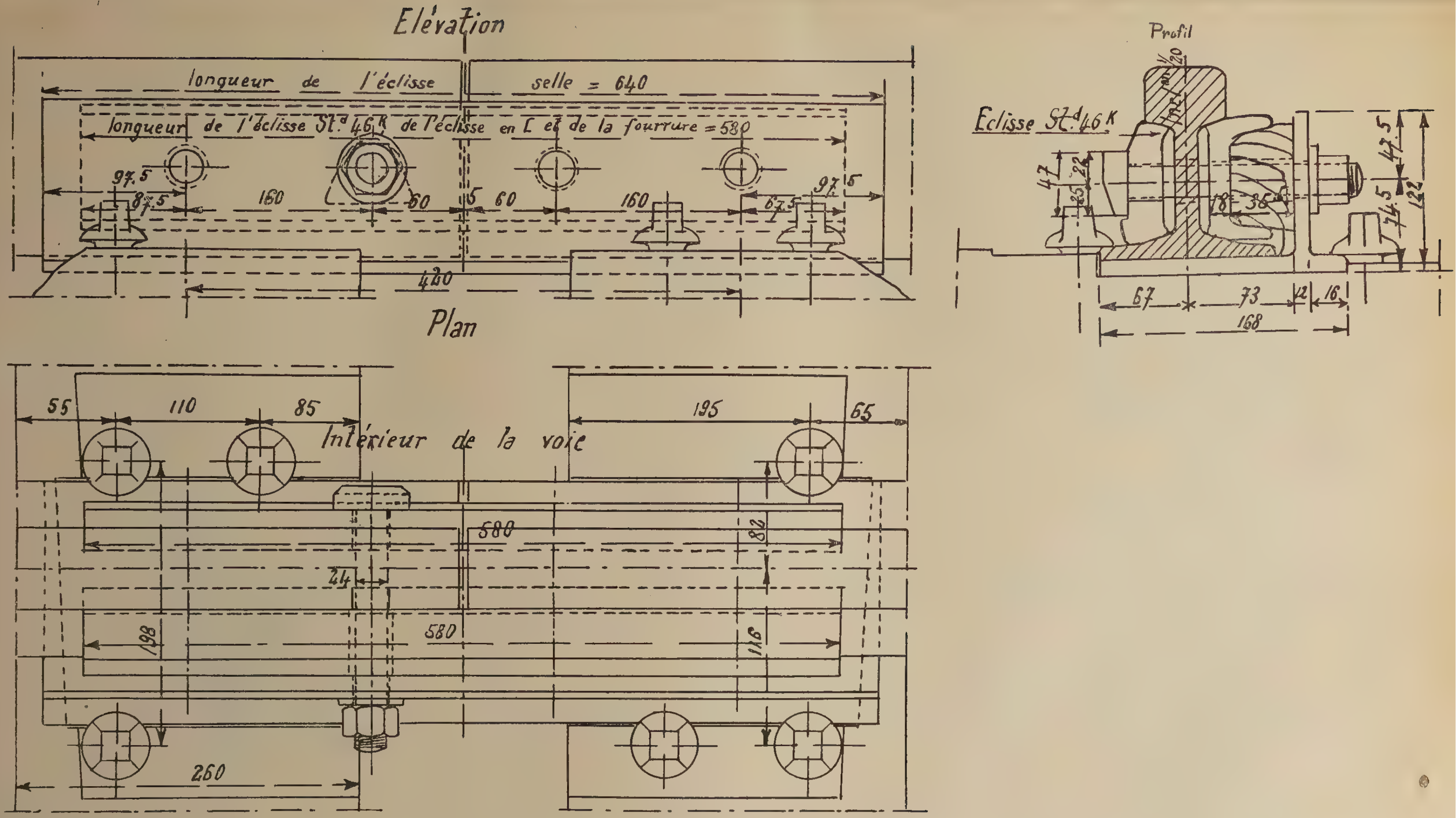


Fig. 43. — French Nord Railway. — Joints with distance piece for 46-kgr. (92.7 lb. per yard) rails.

Explanation of French terms: Longueur de l'éclisse-selle = 640 = Length of bed plate = 25 1/4 inches. — Longueur de l'éclisse St^{d} 46 k, de l'éclisse en [et de la fourrure = 580 = Length of standard fishplate for 92.7-lb per yard rail, of [shaped plate and of distance piece = 32 13/16 inches. — Profil = Cross section.

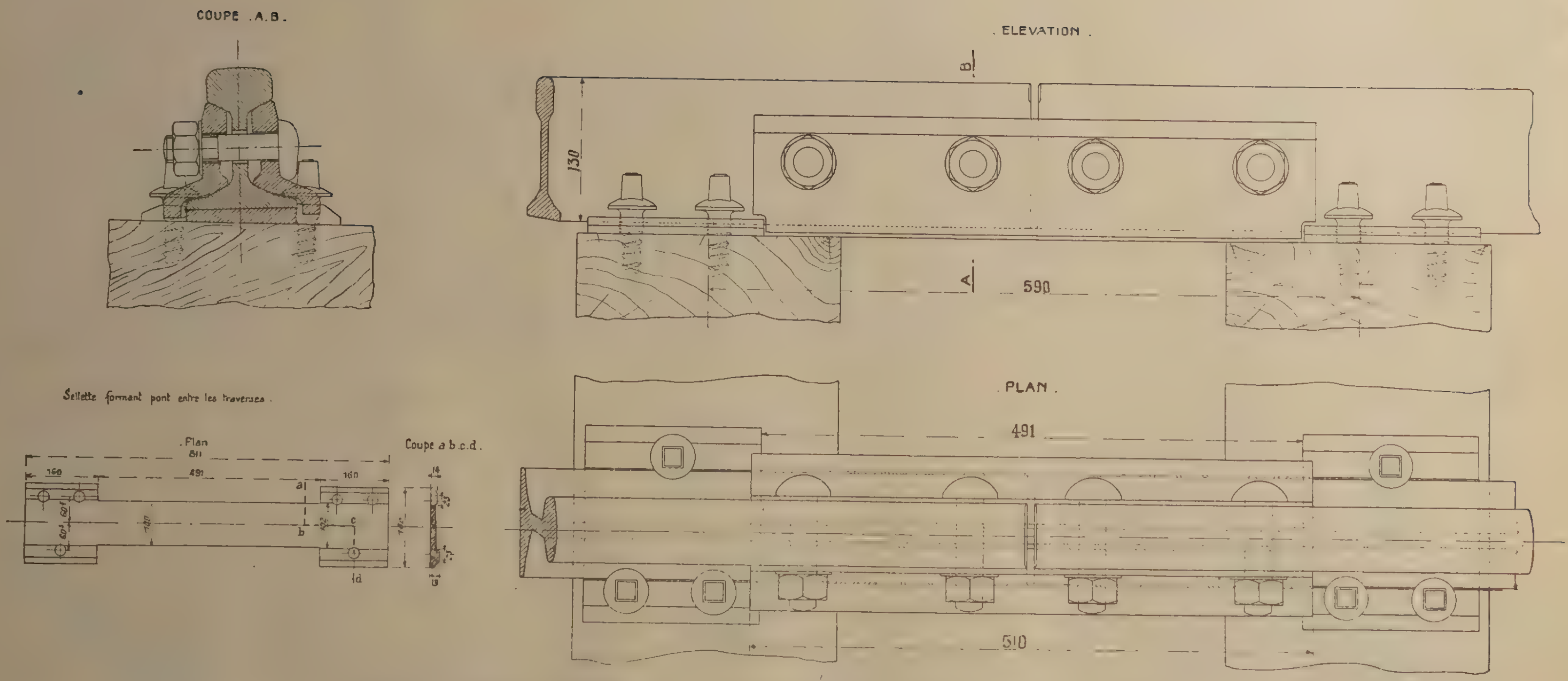


Fig. 44. — Italian State Railways. — Bridge joint for 36-kgr. (72.6 lb. per yard) rails.

Explanation of French terms : Sellette formant pont entre les traverses = Bridge plate between sleepers.

they have not yet been able to form any final conclusions thereon.

The Swedish State Railways use a joint having twin sleepers bolted together, a joint with fishplate 0.915 m. (3 feet) in length spanning three sleepers, and a joint (fig. 45) with sole plates forming a bridge between two sleepers and carrying a jaw embracing the foot of the rail.

The Rhætian Railways (Switzerland) are about to replace the angle fishplate by shorter, flat plates 0.60 m. (12 inches) long.

The Czecho-Slovakian Railways use a bridge joint for the 44.35-kgr. (89.4 lb. per yard) rail, an improved suspended joint with deep fishplates, and the suspended joint of the Janonsek-Guba type for rails not drilled at the end; this type of joint gives satisfaction so along as the rails fishplates and wedges do not show any appreciable wear, but when this is not the case, the cost of maintenance of the arrangement becomes very high so that no further application of the arrangement will be made.

We find that a new type of joint, the chevron fishplated joint, has been the subject of experiment since 1925.

This joint is based upon a new principle, and it is of the greatest importance that the tests which, if successful, will transform the whole question of the fishplating of rails, should be followed up.

§ 3.	*Have you carried out simultaneous and comparative tests of the following types of joints. — (London Congress. Conclusion No. 2) :*			*What have been the conclusions of the tests?*
—	a) *Bridge joints in which the ends of the rails rest on a steel member forming a bridge between the two joint sleepers.*	b) *Suspended joints in which the joint sleepers are brought close together until they touch.*	c) *Joints, not involving drilling the webs of the rails.*	
gian National Railway Company.	Yes.	Yes.	No.	The duration of the tests is not long enough for any conclusions to be drawn.
nish State Railways . . .	No.	Yes.	No.	
nish State Railways . . .	No.	Yes.	No.	...
ris Girdle Railway	No.	No.	Yes, and are making an extended application thereof.	...
Railway (France) . . .	Yes.	Yes. (The sleepers are brought very close together but are not touching.)	Yes.	The tests only started in 1927 and it would be premature to draw any conclusions therefrom.

§ 3 (*continued*).	*Have you carried out simultaneous and comparative tests of the following types of joints, — (London Congress. Conclusion No. 2)* :			
—	a) *Bridge joints in which the ends of the rails rest on a steel member forming a bridge between the two joint sleepers.*	b) *Suspended joints in which the joint sleepers are brought close together until they touch.*	c) *Joints, not involving drilling the webs of the rails.*	*What have been th[e] conclusions of th[e] tests?*
Midi Railway (France) . . .	Yes.	No.	No.	The tests of joint[s] *a*) have been give[n] up since the intro[-]duction on the lin[e] of the Company o[f] the chevron fis[h] plated joint.
Nord Railway (France) . . .	Yes.	No.	Yes.	Tests too recent fo[r] any conclusions t[o] be drawn.
Paris, Lyon & Mediterranean Railway (France).	No.	Yes.	No.	This system has made a test of joint *b*) with sleepers in contact but it has not been continued owing to the problem of obtaining supplies of sleepers of the kind required.
Italian State Railways . . .	No.	Yes.	No.	This Railway has made tests of joint *b*), but allowed them to drop on account of the difficulty experienced in packing the sleepers.
Swedish State Railways . . .	Yes.	Yes.	No.	...
Nora-Bergslagen Railway (Sweden).	Yes, but only in points.	No.	No.	...
Rhætian Railway (Switzerland).	No.	Yes.	No.	...

We find that with very few exceptions, no tests on any one Railway System have been made to obtain comparative data on the three types of joints which were dealt with at the London Congress.

Isolated tests of each of the types has been made with, as a rule, satisfaction, but without it being possible to establish any comparison between the three types.

There has been some development in the design of joint with very closely placed joint sleepers. In order not to have to use as joint sleepers squared sleepers a certain number of Railways have not laid the said sleepers absolutely in contact but at a distance between centres varying from 0.26 to 0.28 m. (10 1/4 to 11 1/32 inches).

The few really comparative tests of the three types of joints recommended, are still of too recent date for any conclusions to be drawn as to their relative value.

We consider that it is of value to continue these tests and even to carry out new tests in such cases where tests of this kind have not already been made.

§ 4. — *Have you introduced into your specifications for fishplates any clauses intended to exclude brittle metal? Is this done for example in the case of fishplates the metal of which has been heat treated? If so, give particulars of these requirements and of the test methods used to see they have been carried out.*

The Belgian National Railway Company has since 1927 laid down a requirement that all fishplates are to be heat treated, Martin steel being used for junction fishplates, whereas for ordinary fishplates the method of manufacture of the steel is left to the suppliers. The rejection tests provided in the specifications include ball testing, tensile bending, texture, resilience on notched bars and macrographic. Micrographic tests are also specified for check test purposes.

The Bulgarian State Railways use fishplates made from 50 to 60-kgr. (25.4 to 38.1 Engl. tons per sq. inch) tensile steel. These fishplates are annealed after completion.

The Egyptian State Railways impose the conditions of the British Standard Specification.

The Finnish Railways merely specify the annealing of the fishplates, if the holes or slots in them have been punched cold.

The North of Spain Railway specifies a drop test on a joint of two pieces of rail 1.50 m. (4 ft. 11 in.) long fishplated together and carried on supports spaced 1.10 m. (3 ft. 7 5/16 in.) apart. The 200-kgr. (440-lb.) tup falling a height of 2 m. (6 ft. 6 3/4 in.) on such a test joint built up of rails of 42.50-kgr. (85.4 lb. per yard) should not deflect more than 10 mm. (3/8 inch). The tup when falling from a height of 4 m. (13 ft. 1 1/2 in.) should not cause any cracks or fracture.

The great French Railway Companies and the Algerian Lines of the State only require in their specifications in order to detect brittleness of fishplates not heat treated, the cold bend test as follows: a prismatic test piece not less than 250 mm. (9 7/8 inches) long, 40 mm. (1 9/16 inches) wide and 20 mm. (25/32 inch) thick (or of the thickness of the fishplate tested if this is thinner than 20 mm.) shall be cut from a fishplate.

This test piece shall be bent cold until the two ends are brought parallel one to the other with a distance between them equal to:

— zero (bent right over) for steel the minimum breaking strength of which is

40 kgr. per mm^2 (25.4 Engl. tons per sq. inch);

— to the thickness of the test piece for steels the breaking strength of which is 48 kgr. (30.5 Engl. tons per sq. inch);

— to one and a half times the thickness of the test piece for steel of a strength equal to, or higher than 55 kgr. (34.9 Engl. tons per sq. inch).

The test pieces shall comply with this test without there being any tearing on the outside face of the test piece nor any separation.

In the case of fishplates heat treated, these Railways have developed a shock test on notched fishplates according to the following clauses:

The fishplates for 46-kgr. (92.7 lb. per yard) standard rails are prepared as as shown in figure 46 so as to form test pieces for the drop test.

These test pieces placed with the nick downwards on two supports 0.50 m. (1 ft. 7 11/16 in.) apart shall stand without fracture a blow from a 300-kgr. (660-lb.) tup falling immediately above the notch from a height of 2.75 m. (9 ft. 9/32 in.).

For record purposes, the test is continued until the test piece breaks by successive blows from the tup falling from the same height.

For fishplates of other sections the form and dimensions to be given to the test piece as well as the height of fall of the tup are stated on the orders.

The Gafsa Railway (Tunis) requires the fishplates to be annealed; they are made of Martin steel and must give 48-kgr. (30.5 Engl. tons per sq. inch) $< R <$ 55 kgr. (34.9 Engl. tons per sq. inch), $A \geqslant 20$ % in the tensile test and 12 Kg.-M. per cm^2 (555 foot-pounds per sq. inch) on test pieces measuring $55 \times 10 \times 10$ ($2\ 3/16 \times 3/8 \times 3/8$ inch) notched as the Mesnager type for the resilience tests. The fishplates have in addition to be bent cold through 90°, in the notched part, without showing any signs of cracks.

This Railway will require when next ordering fishplates, that the annealing shall be followed by cooling off in the air in order to safeguard itself against certain cracks that have revealed themselves in service.

The Italian State Railways have prescribed since 1927, the annealing of fishplates in order to avoid cold work hardening resulting from machining the parts cold, and check this annealing, by resilience tests with Mesnager type notched test bars.

The Serbian State Railways specify for the manufacture of their flat fishplates, a steel of a breaking strength of 45 to 55 kgr. (28.6 to 34.9 Engl. tons per sq. inch) with 20 % elongation; for their other fishplates the steel shall give 38 to 50 kgr. (24.1 to 31.7 Engl. tons per sq. inch) with 25 % elongation.

The Swedish State Railways and the Nora-Bergslagen Railway specify that the fishplates shall be made of steel of a breaking strength exceeding 45 kgr. (26.8 Engl. tons per sq. inch) and that the completed fishplate shall stand in line with the holes a bend test through 90°, without any signs of fracture.

The Swiss Federal Railways specify annealing after manufacture for all fishplates, the steel for which shall have a breaking strength of between 35 and 45 kgr. (22.2 and 28.6 Engl. tons per sq. inch).

We find that excluding the Belgian National Railway Company, and the Gafsa Railway (Tunis), the different Railway Companies do not lay down any very dif-

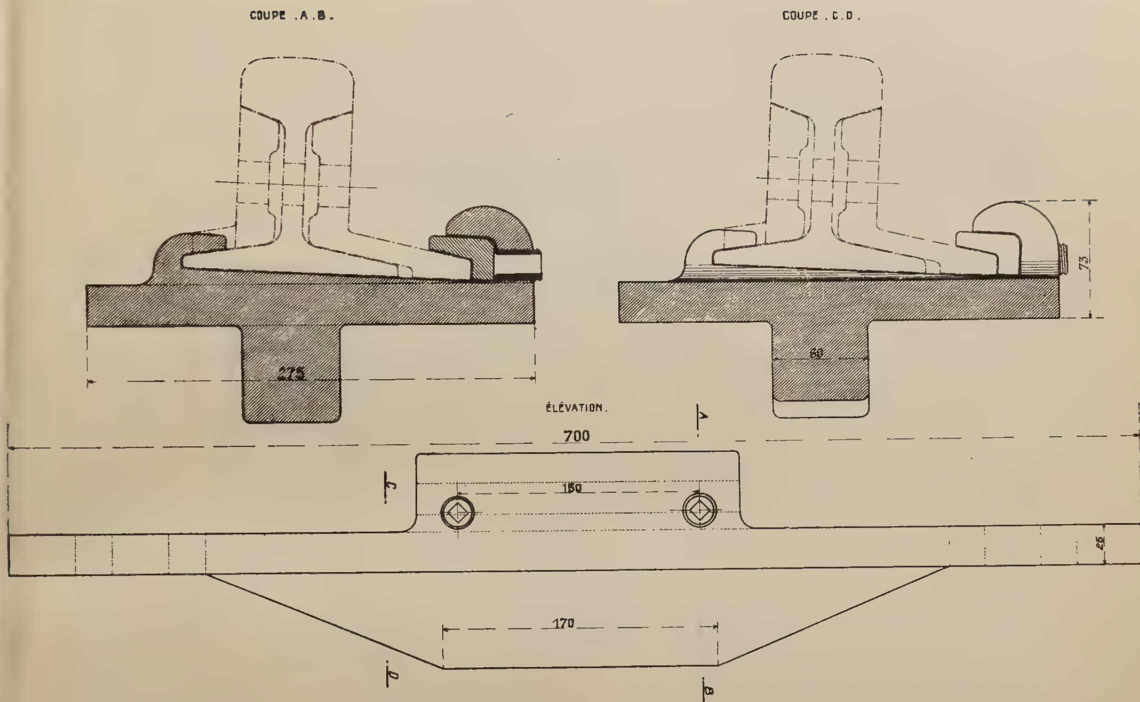


Fig. 45. — Swedish State Railways. — Bridge joint with jaw gripping the foot of the rails.

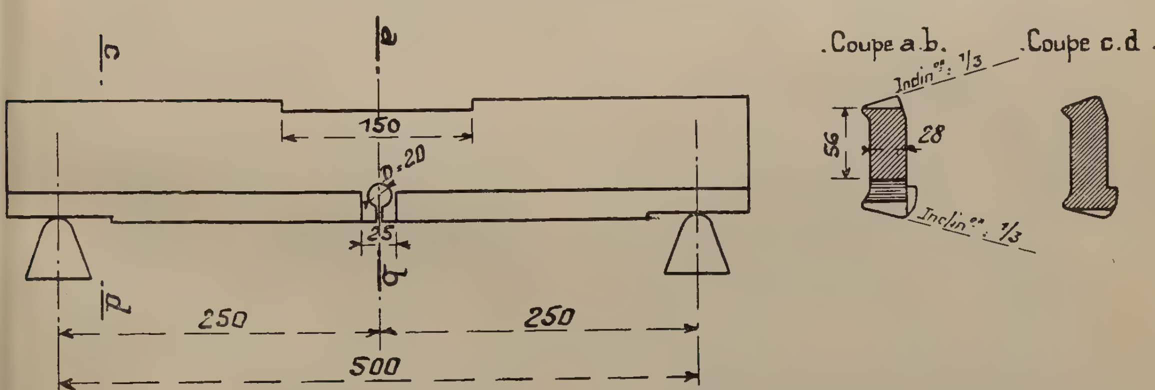


Fig. 46. — Main French Railways. — Fish plates for 46-kgr. (92.7 lb. per yard) rails prepared for the shock tests laid down for heat treated fish plates.

ficult conditions as regards the inspection of ordinary fishplates.

The quality of the steel falls between wide limits, and, except for annealing which is required after machining, by a number of Companies, the Specifica-

tions do not contain any particular clauses dealing with brittleness in the metal.

The great French Companies and the Belgian National Railway Company appear to be the only ones using generally heat treatment.

As a matter of information, it should be noted that a drop test on notched test fishplates is specified by the French Railways, and forms one method of eliminating brittle metal.

§ 5. — *What means have you adopted to insulate electrically the joints ?*

The Belgian National Railway Company uses fishplates in wood or steel fishplates with insulated distance pieces of vulcanised fibre or of leather.

The Danish State Railways use fishplates made of beech impregnated with varnish for insulated rail joints.

The North of Spain Railway uses wooden fishplates in station lines, and the Weber joint on running lines.

The Finnish State Railways use steel fishplates with insulating distance pieces made of fibre.

The great French Railways use, as in 1925, joints with steel fishplates having insulated distance pieces in fibre or of cellulose impregnated with synthetic resin, the joints being strengthened by means of side rails fastened to the neighbouring sleepers, fishplates in wood, deep flanged half fishplates, and joined on metal soleplates with fishplates of wood.

They are experimenting with fishplates of bakelite (fig. 47); the thickness of the fish plate can be reduced owing to greater strength of the bakelite.

The Algerian Lines of the Paris, Lyons & Mediterranean Railway, the Italian State Railways, the Norwegian State Railways, the Roumanian State Railways, the Swedish State Railways, the Swiss Federal Railways, and the Czecho-Slovakian State Railways, use steel fishplates with insulating distance pieces in fibre.

The Netherlands State Railway Company, and the Dutch Railway Company use the Weber joint.

The Serbian State Railways use fishplates in wood.

We find that no new methods of providing insulated joints have been brought forward since the last Congress.

We consider that the preference should be given to joints using fishplates in wood, ordinary suspended joints, or bridge joints.

§ 6. — *What methods have you taken to ensure electric continuity of a line of rail in spite of the presence of the joints.*

The Belgian National Railway Company, and the Belgian Light Railway Company, use bonds af annealed copper wire welded to the rails.

The Danish Railways, bond the rails together by means of copper wire secured by tapered bolts.

The Madrid to Saragossa and to Alicante Railways, use double copper wires riveted into the web of the rails to be bonded together.

The North of Spain Railway, uses copper braid riveted to rails of 42.5 kgr. (85.7 lb. per yard) section and bonds of copper cable welded to the rails in station lines. When installing the automatic block, the rails are bonded by means of galvanized iron wire 4 mm. (5/32 inch) in diameter, secured to the rails by means of channel pins.

The Finnish State Railways use metal bonds welded to the head of the rails near to the joints or secured to the web of the rails close to the end of the fishplates.

The French State Railways use copper cable of suitable diameter the ends of

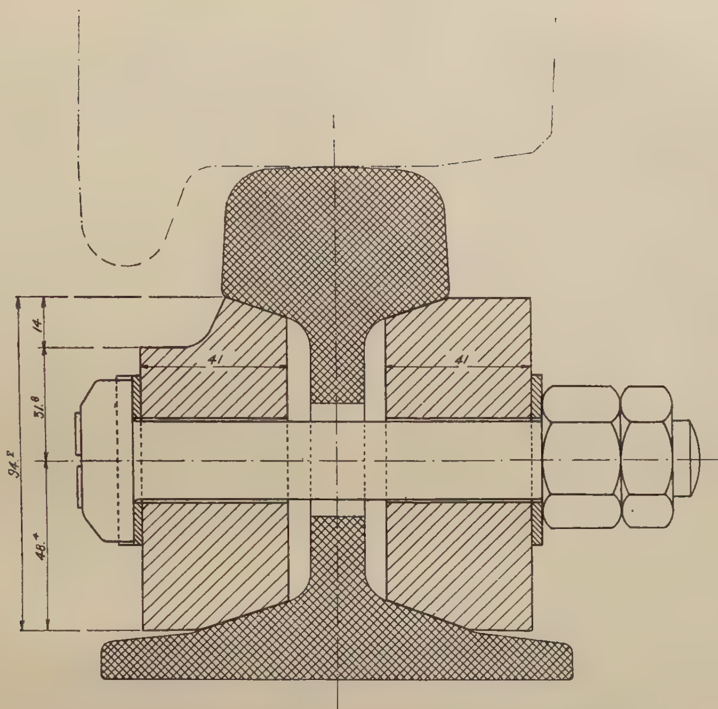


Fig. 47. — Main French Railways. — Fishplates in bakelised wood for joints electrically insulated.

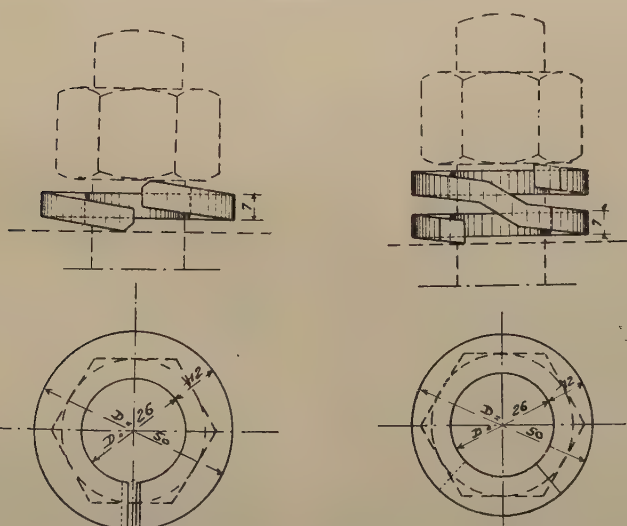


Fig. 48. — Various Railways. — Single and double coil Grover washers.

which are forced into holes prepared near to the end of the rails. They also use double bonds in 4-mm. (5/32 inch) iron wire secured to the web of the rail with channel pins in coppered steel.

The Alsace and Lorraine Railways use bonds of copper wire.

The Paris Girdle Railway uses twin wires to bond the rails.

The French Est Railway uses a bare copper wire fastened to the web of the rails by means of channel pins. In recently laid lines and on lines carrying heavy traffic, the copper wire is duplicated by a second bond in galvanized iron wire fastened in the same way.

The French Midi Railway uses, on the electrified lines, special bonds composed of thirteen copper strips [2 of 5/10 of a mm. (0.0197 inch) and 11 of 3/10 of a mm. (0.0118 inch) thickness], but have found that the use of the chevron fishplate makes any bond unnecessary, the said fishplate giving sufficiently good contact between the different parts of the joints. For lines not electrified this Railway uses 4-mm. (5/32 inch) diameter steel wire.

The French Nord, Paris-Orleans, and Paris, Lyons & Mediterranean Railways, use 4-mm. (5/32-inch) diameter steel wire for bonds, secured to the web of the rails by means of channel pins.

The Société des Transports en Commun de la Région Parisienne, either welds the rails together, or welds the fishplates to the rails; they also weld copper bonds to the foot of the rails.

The Italian State Railways use woven copper braid secured to the rails and to the fish plates.

The Lombardy Electric Traction Company (Italy) uses copper bonds ending in a round head with a split pin. It is about to test bonds in copper with the heads in iron welded to the rails.

The Norwegian State Railways use copper bonds welded to the rails or copper wire secured to the rails by means of channel pins.

The Netherlands State Railway Company, and the Dutch Railway Company, use copper bonds.

The Rumanian State Railways use bonds of copper wire.

The Swedish State Railways use bonds fastened to the rails.

The Swiss Federal Railways use copper bonds welded to the rails.

The Rhætian Railways, Switzerland, use bonds of 6 mm. (1/4 inch) diameter copper wire, 0.85 m. (33 1/2 inches) in length, fastened to the rails by means of channel pins.

The Czecho-Slovakian Railways use copper cable welded to the head of the rails on the outside about 10 mm. (3/8 inch) below the running surface.

We find that to obtain electric continuity two cases are to be considered :

1. Electric conductivity through the joint to ensure the return of the motor current on lines with electric traction.

2. Electric conductivity of the joints to ensure the proper working of the tracks circuits used for signalling purposes.

1st Case. — *Electric connections for the return current.*

As this current varies and may attain high values, the electric connections connecting two rails together are usually formed of cables, plaited wire, or wire ribbon made of copper of suitable sections bolted or welded to the rails.

The Société des Transports en Commun de la Région Parisienne (France) welds the rails together or weld the rails to the

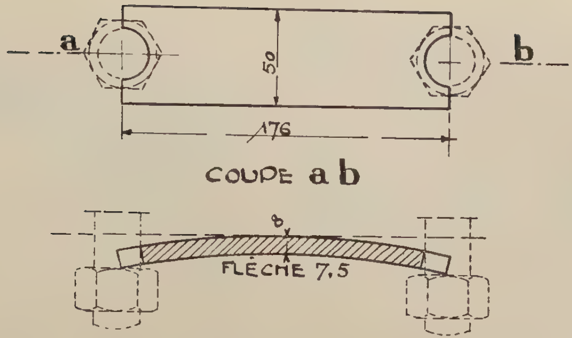


Fig. 49. — Various Railways. — Reiss plates

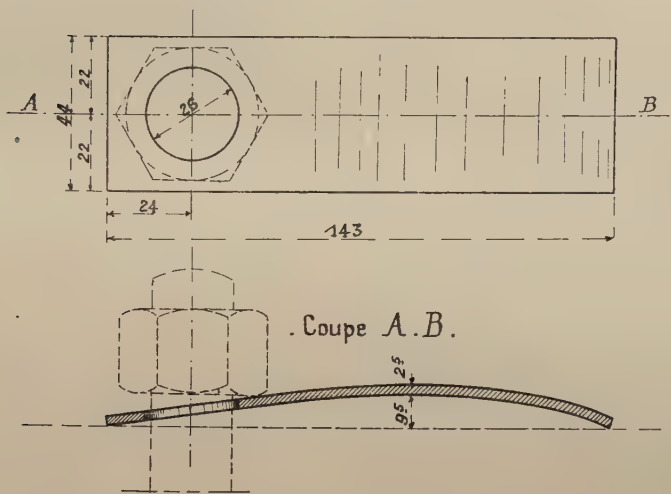


Fig. 50. — Various Railways. — « S » spring plates.

fish plates, so as to obtain electric continuity of the line of rail.

The French Midi Railway has found that its new type of fish plate (the chevron fish plate) is sufficient in itself to give this continuity and consequently has given up any other supplementary connection.

2nd Case. — *Electric connections for track circuits.*

In the majority of instances the bonds are made by metal wires secured to the rails by channel pins, or more rarely by bolts. The bond is either a single copper wire, or a copper and a steel or iron wire, or two steel or iron wires.

The Italian State Railways, use a bond connecting one rail to the end of the fishplate and a second connecting the other end of the fish plate to the second rail.

This arrangement is more complicated than the ordinary method of connecting together the two rails without touching the fishplate.

We think that the use of iron or steel

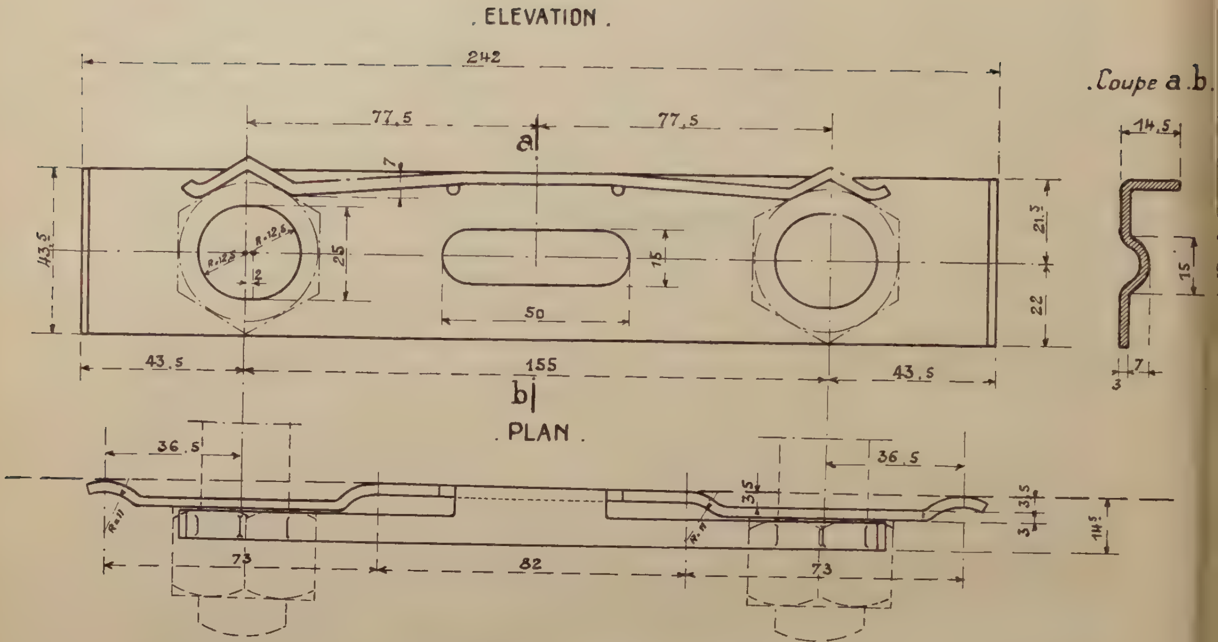


Fig. 51 — Various Railways. — Brandt plates.

wire secured by channel pins is a particularly good solution of the question at reasonable cost for track circuits of moderate length.

We find that fishplate bolts are universally made of mild steel or at most of steel of a quality of R = 50 kgr. (31.7 Engl. tons per sq. inch).

No Railway appears to have found any need to use special steels for these bolts.

The means employed to prevent the bolts from turning when tightening up the nut, are either a glut in a corresponding groove in the fishplate, or an oval or square collar with oval or square holes in the fishplate or a special head bearing in a groove or in a slot in the fishplate. This last arrangement which is most widely used, appears to be preferable to the two former as it avoids any special machining of the fish plates.

Various devices have been experimented with by various Companies, with a view to preventing the nuts slacking back in service.

The Grover washer is the most widely used, and has been used for the longest time. The Reiss plate, also, is giving satisfaction.

The other fittings used, have been too recently employed for any conclusions to be drawn at present, as to their value, and as to their superiority over the two arrangements quoted above.

Most of these devices are so arranged as to hold the fishplate against the rail with practically constant pressure in spite of wear of the wearing surfaces of the fishplates. If care is taken moreover, never to completely take up the elastic range of these details, there is no danger of tightening up the bolts excessively, and

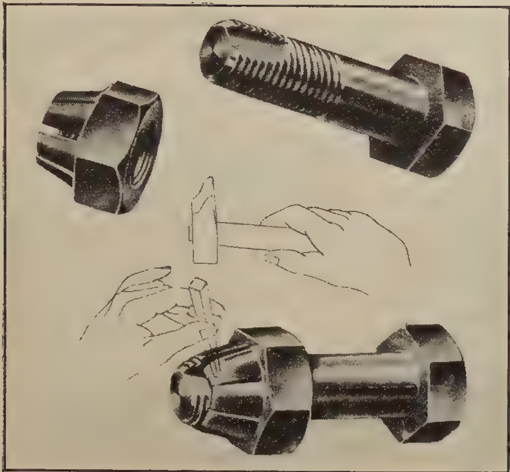


Fig. 52. — Various Railways. — Lecloux bolts.

in this way there is no fear of stretching them beyond the elastic limit.

With the same object, a certain number of Railways limit the length of the spanner used.

SUMMARY.

A. — Broken rails.

On the main lines of the Railway Companies covered by our enquiry, the superstructure of the track is generally built up as follows :

— the rails weigh from 45 to 50 kgr. per linear metre (90.7 to 100.8 lb. per yard).

— the number of sleepers is as high as 1 800 per kilometre (3 420 per mile);

— the ballast, broken up so as to pass through a 6-cm. (2 3/8-inch) ring has a depth of 15 to 25 cm. (6 to 10 inches) for the packing layer, under which is found occasionally, and with great benefit, an underlayer in fine material of from 20 to 25 cm. (8 to 10 inches) depth.

This superstructure can carry an axle load up to 20 tons and would appear to be suitable for axle loads up to 22 tons.

The number of sleepers can be increased if considered desirable without fear of causing the rails to break as a result of altering the points of support.

The usual length of rail is 18 metres (59 ft. 5/8 in.), and there is a tendency to increase this length, in order to reduce the number of joints and consequently their drawbacks. At special places where there is a particular advantage in reducing the number of joints, and where the effects of temperature variations need not be feared, rails of great length can be obtained by welding end to end the ordinary rails : welding by the aluminothermic process has not revealed any danger so far as safety is concerned.

The superstructure of secondary lines is less uniform because they are frequently built up of rails and sleepers from the main lines when these lines have been strengthened and relaid.

Breakages and defects in rails in service have continued to be carefully investigated by the Railway Companies either alone or in collaboration with the manufacturers of rails. The value of this examination, cannot be too strongly stressed, even if it does not lead to any immediate and well defined conclusion.

It would appear most desirable to cooperate with the metallurgists as is done, for example, in France.

As a result of such investigations, seseveral Railway Companies have stiffened up the requirements of their Specifications with a view to eliminating rails with segregation and more particularly, by adding macrographic tests as rejection tests. It would be of value to carry still further the investigations into the rela-

§ 7.	*What metals do you use for fish pla*		
	Kind of metal.	*Breaking strength. Kgr. per mm2 (Engl. tons per sq. inch.).*	*Elastic limit.*
Belgian National Railway Company.	Steel.	38 to 44 (24.1 to 27.9).	...
Belgian National Light Railway Company.	Steel.	42 (26.7) minimum.	...
Bulgarian State Railways	Steel.	38 to 44 (24.1 to 27.9).	...
Danish State Railways	Steel.	38 to 50 (24.1 to 31.7).	...
Egyptian State Railways	Martin steel.	...	...
Central of Aragon Railway (Spain).	...	...	...
Madrid to Saragossa and to Alicante Railway (Spain).	Steel.	38 (24.1) minimum.	...
North of Spain Railway	Steel.	45 (28.6) minimum.	25 kgr. (15.9 Englis tons per squa inch) minimum.
Finnish State Railways	Steel.	38 to 48 (24.1 to 30.5).	...
French State Railways	Steel.	40 to 48 (25.4 to 30.5).	...
Alsace-Lorraine Railways (France) .	Steel.	35 (22.2) minimum. 40 (25.4) minimum. 48 (30.5) minimum.	...
Paris Girdle Railway	Steel.	Do.	...
French Est Railway	Steel.	40 to 48 (25.4 to 30.5).	...
Midi Railway (France)	Steel.	48 (30.5) minimum.	...
French Nord Railway	Steel.	40 (25.4) minimum.	..

...ngation.	What arrangement do you use			What steps do you take to limit the force with which the bolt is tightened up and to prevent excessive tightening?
	To prevent the bolts from turning when tightening the nut?	*To prevent the bolts from slacking back in service?*	*To tighten the fish plates against the rail with practically constant pressure in spite of wear of the wearing surfaces?*	
minimum.	Special head.	Grover washers, Reiss plates, « S » spring plates, Brandt plates, Lecloux bolts (figs. 48 to 52).	Periodic tightening up of the nuts.	Length of the spanner is limited and spanner bars not allowed.
minimum.	Glut or special head.	Square washer.	Nothing.	Length of the spanner limited.
...	Special head.	Washers and special locket plates.	Tightening of the bolts.	None.
minimum.	Oval collar.	Spring washers.	Spring washers.	Length of the spanner limited.
...	Nothing.	Nothing.	Nothing.	None.
...	Oval collar or special head.	Spring washers.	...	...
minimum.	...	...	...	...
minimum.	Special head.	Nothing.	Periodic tightening up.	Length of the spanner limited.
minimum.	Do.	Grover washers.	Grover washers.	None.
minimum.	Do.	Grover washers and various other fittings.	See previous column.	None.
minimum. minimum. minimum.	Do.	Grover washers. Brandt plates.	Reiss plates.	None.
Do.	Do.	Grover washers.	Packing plate.	Instructions issued to the staff.
minimum.	Do.	Grover washers, Reiss plates, Montupet brakes, Halloy nuts (figs. 53 to 54).	See previous column.	Length of the spanner limited.
minimum.	Special head or groove.	Spring washers.	Nothing.	Length of the spanner limited.
minimum.	Special head.	Single or double Grover washers, Reiss plates, Brandt plates, Halloy nuts, Montupet brakes.	Reiss plates, Brandt plates, Halloy nuts, Montupet brakes.	Length of the spanner limited.

§ 7 (*continued*).	*What metals do you use for fish pla*		
	Kind of metal.	*Breaking strength.* — *Kgr. per mm² (Engl. tons per sq. inch.).*	*Elastic limit.*
Paris-Orleans Railway	Steel.	40 (25.4) minimum.	...
Paris, Lyons & Mediterranean Railway.	Steel.	40 (25.4) minimum.	...
Société des Transports en commun de la Région parisienne (France).	Steel.	40 (25.4) minimum.	...
Algerian State Railways	Steel.	40 (25.4) minimum.	...
Paris, Lyons & Mediterranean Railway (Algerian Lines).	Steel.	40 (25.4) minimum.	...
Gafsa Railway (Tunis)	Steel.	40 (25.4) minimum.	...
Tunisian Railway Company	Steel.	40 (25.4) minimum.	...
French West African Colonial Railways.	Mild steel.	...	...
French Dahomey Railway Company .	Steel.	40 (25.4) minimum.	...
Damas-Hamah Railway and Extensions (Asia Minor).	Steel.	...	...
Italian State Railways	Steel.	38 (24.1) minimum $R \times A \geqslant 980$.	...
Prince Henry Railway & Mines . .	Mild steel.	...	...
Norwegian State Railways	Mild steel.	...	...
Netherlands State Railway Company.	Steel.	42 to 50 (26.7 to 31.7).	...
Rumanian State Railways	Very mild steel or iron.	...	...
Serbian State Railways	Steel.	38 to 50 (24.1 to 51.7)	...
Swedish State Railways	Steel.	44 (27.9) minimum.	...
Nora-Bergslagen Railway (Sweden) .	Steel.	44 (27.9) minimum.	...
Swiss Federal Railways	Steel.	35 to 45 (22.2 to 28.6).	...
Czecho-Slovakian State Railways . .	Steel.	38 to 50 (24.1 to 31.7).	...

...t?	What arrangement do you use			
Elongation.	*To prevent the bolts from turning when tightening the nut?*	*To prevent the bolts from slacking back in service?*	*To tighten the fish plates against the rail with practically constant pressure in spite of wear of the wearing surfaces?*	*What steps do you take to limit the force with which the bolt is tightened up and to prevent excessive tightening?*
% minimum.	Special head.	Grover washer, Reiss plates.	Brandt plates, Montupet brakes.	...
% minimum.	Special head.	Grover washer.	Tests are being made.	Length of the spanner limited.
% minimum.	Groove in the fishplate.	Grover washer.	Nothing.	Nothing.
% minimum.	Groove in the fishplate or special head.	Grover washer.	Plate packing.	Length of the spanner limited.
% minimum.	Special head.	Nothing.	Nothing.	Length of the spanner limited.
% minimum.	Groove in the fishplate.	Grover washer.	Do.	Nothing.
% minimum.	Groove in the fishplate.	Grover washer, « S » spring plate.	Do.	...
...	Special head.	Grover washer.	Do.	Length of the spanner limited.
% minimum.	Glut.	Grover washer.	Do.	Length of the spanner limited.
...	Special head.	Grover washer.	Do.	Nothing.
× A ⩾ 980.	Glut or special head.	Grover washer.	Plate packing.	Do.
...	Groove in the fishplate or special head.	Lecloux bolts, Palmutter nut (fig. 55).	Nothing.	Do.
...	Oval collar.	Elastic washer.	...	...
% minimum.	Oval or square collar.	Grover washer.	Nothing.	Length of the spanner limited.
...	Oval or square collar.	Nothing.	Spring washer.	Length of the spanner limited.
% minimum.	Special head.	Grover washer.	Nothing.	Nothing.
...	Square collar.	Spring washer.	Spring washer.	Length of the spanner limited.
...	Square collar.	Nothing.	Periodic tightening up.	Nothing.
...	Special head.	Spring washer.	Nothing.	...
...	Special head.	Grover washer.	Grover washer.	Length of the spanner limited.

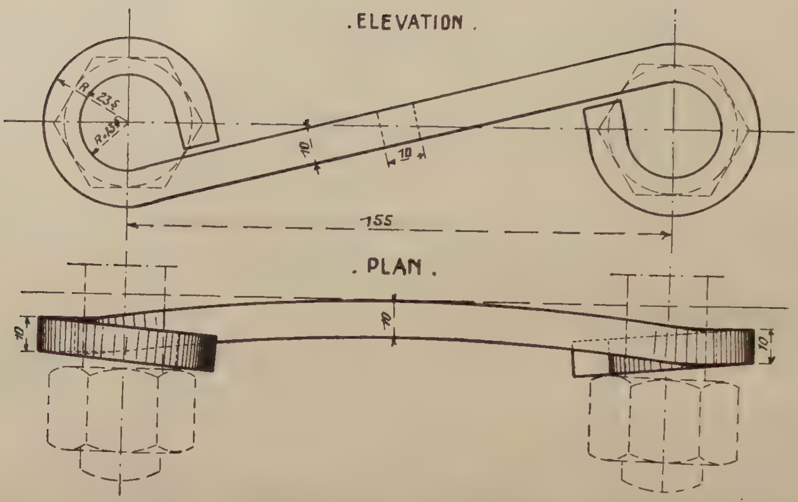


Fig. 53. — Various Railways. — Montupet brake.

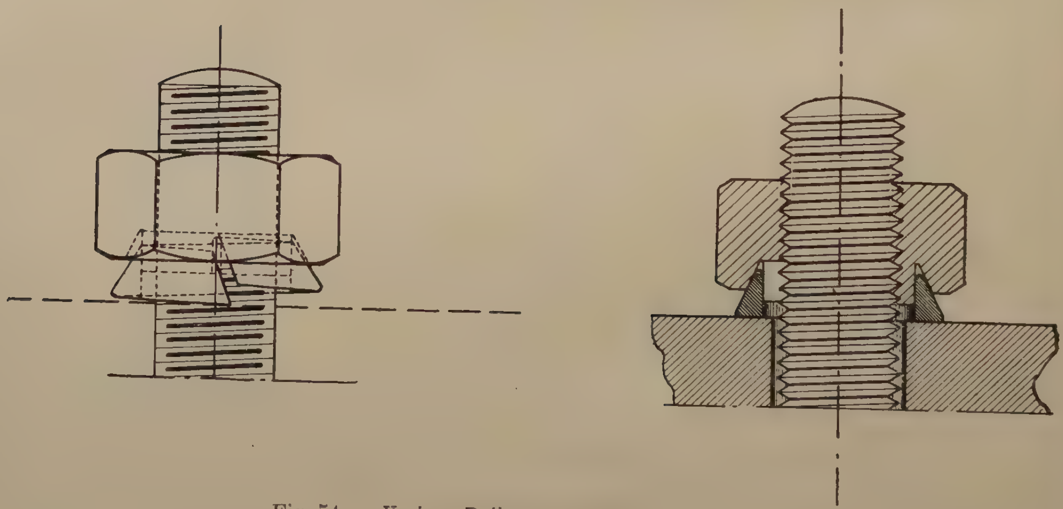


Fig. 54. — Various Railways. — Halloy nut.

tions between cause and effect as regards segregation and defects in rails occurring in service.

Investigations are still being made, with a view to obtaining less brittle rails. A note should be made of the increased use of heat treated rails in France, as a result of the remarkable tests carried out by the Neuves-Maisons works which showed how much an appropriate heat treatment could increase the strength of rails against the development of superfi-

cial fissuration due specially to the slipping of locomotives.

The tests used to demonstrate the brittleness of rails (resilience tests) are most often made on small test pieces, and give information too much affected by the test pieces themselves for them to be introduced as rejection tests in the Specifications. It would be of value if a less localised test by which it would be possible to ascertain that the whole section of the rail was not brittle, could be developped. Until such a test could be used to eliminate brittle rails it could be used to give information as to the quality so that premiums could be awarded. In this order of ideas the drop tests devised by Mr. Merklen and carried out on a rail with a 2 mm. (0.079 inch) deep by 2/10 mm. (0.0079 inch) wide notch, should be noted.

Several Railways have developed the methods of inspection in use to reveal in the track defects that might develop into fractures.

It appears desirable to carry out at least once a year, an inspection and hammer test of the rails.

As regards the stresses set up in the rails by locomotives and rolling stock generally running over them we find :

— On the one hand that the progress realised in the design and construction of locomotives is making any lack of balance of the said engines, less and less harmful.

— On the other hand the shock due to flat spots on wagon wheels can be reduced by not allowing for such flats a greater depth than 3 mm. (0.118 inch).

The whole of the Railway Administrations agree in asking the *Bulletin of the Congress* to continue to publish statistical information relative to the breakage of rails. The present tables could be modified usefully in order, for example, to separate fractures in tunnels, from fractures in the open, and to bring out the percentage of fractures on curves.

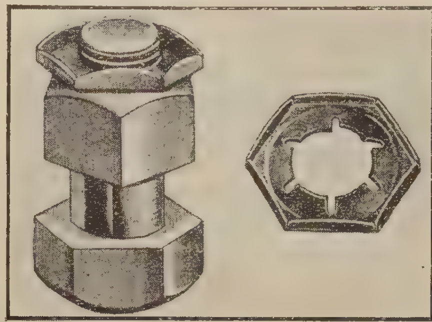


Fig. 55. — Various Railways. — Palmutter nut.

B. — **Wear of the rails.**

All the railways have observed the same forms of wear :

a) wear of the running surface by abrasion without side flakings;

b) wear by the formation of side flakes which are torn off, or ground off by the passing wheels;

c) side wear of the side of the head of the rail on lines laid on curves;

d) wear through hammering at the joints or at gaps in the points (crossings, bridges, etc.);

e) corrugated wear;

f) wear through rusting.

g) wear of the foot of the rail through scaling, due to the sleepers, packings or bearings on which it rests.

Corrugated wear appears to affect light railways and tramways especially.

As a rule no quantitative measurements have been made of these different forms

of wear, and it is therefore not possible to establish any ratio between the value thereof on the one hand, and the conditions of the traffic and the characteristics of the superstructure of the track, on the other hand. It would be of interest to form with this object a greater number of test sections.

The Specifications for the supply of rails as a rule do not contain any special requirements in order to obtain the maximum resistance against wear in its different forms.

The usual practice is simply to require a tensile strength above 70 kgr. per mm² (44.4 Engl. tons per square inch), with an elastic limit exceeding 40 kgr. per mm² (25.4 Engl. tons per square inch).

At places where wear is serious, the Companies use with successful results, rails of harder quality (80 kgr. per mm² = 50.8 Engl. tons per square inch), heat treated rails, and details made of manganese or nickel-chrome steel. In order to prevent corrugated wear on tramway lines, it appears to be necessary to push the heat treatment far enough to give the running surface of the top of the rail a martensitic texture.

In order to reduce side wear on the upper rails on curves of small radius, tests have been carried out successfully, with various arrangements of lubricators whereby a lubricant is introduced between the inside vertical face of the head of the rail and the outside of the flanges of the wheels. It would appear advisable to generalise the use of these fittings rather than to use test rails which have shown themselves to be of little value as regards reducing side wear of the rails.

In order to reduce wear through rusting, at places where this is to be particularly feared, such as in tunnels, it appears desirable to use a heavier section rail and to carry out further tests of rails made from copper bearing steel.

Although the use of metal sole plates between the wooden sleeper and the foot of the Vignoles rail is quite usual, it would seem that these plates could be dispensed with advantageously on condition of keeping the rail fastenings properly tightened up; this is the most effective method of preventing wear through the foot of the rail being indented by the sole plate as well as the machined bearing surface of the sleeper being damaged.

C. — Rail joints.

No comparison as regards the strength and the life of the different types of rail joint used by the various Railway Companies can be made, no statistics being kept on this point.

Most of the Railways continue to use the type of joint previously described but improved and strengthened. One really new type of joint should be mentioned; the chevron fishplate type.

Three types of joints were specially considered during the London Congress :

— the bridge joint, in which the end of the rails rest on a metal plate acting as a bridge between the joint sleepers;

— the suspended joint with the sleepers brought together into contact;

— the joint without holes drilled in the web of the rails.

Although a number of Railways have carried out, at least to some extent, tests at the same time with these three types of joints, it is still impossible to say which joint is the best; it should however, be noticed that the suspended joint with the joint sleepers brought close together, is very widely used. It is certainly desirable to continue these comparative tests under the conditions that were re-

commended at London, that is to say that each Railway should carry out experiments on its own line with the different types of joints at the same time.

The metal used for fishplates is not as a rule subjected to any severe reception tests. It would appear desirable to strengthen the specifications so as to eliminate any brittle metal. Heat treatment makes it possible to obtain this result, and it would appear of value that it should be more generally used.

The electrical insulation of the joints, does not appear to have produced any new design. The simplest joint with wooden fishplates, appears to be the best.

To obtain electric continuity, through the joint it appears to be necessary to use copper (cables, braid, ribbons, wire) when it is a question of providing connections for the return of the motor current, or for track circuits of considerable length. Iron or steel wire is sufficient for track circuits of reduced length.

Fishplate bolts are as a rule, made from mild steel. Various devices are employed to prevent the bolts from turning when tightening up the nuts, to prevent them from slacking back in service, and to keep the fishplates tightly pressed against the rails with sufficient strength when a slight slacking off occurs in service. None of the devices appears at the present time to show any definite superiority which would make it desirable to use it in place of any of the others.

[621 .134]

REPORT No. 3

(America)

ON THE QUESTION OF THE IMPROVEMENTS IN THE STEAM LOCOMOTIVE (SUBJECT VI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

by W. L. LENTZ,

ENGINEER, MOTIVE POWER, NEW YORK CENTRAL RAILROAD COMPANY.

Figs 1 to 13 pp. 2116 to 2137.

OUTLINE OF REPORT.

Covering period (years 1920-1928 inclusive).

INTRODUCTION.

There has been such extraordinary development in the steam locomotive, that the Railroads of the U. S. A. have spent, during the last eight years, six and one half billion dollars for new and improved equipment, with which they attained the greatest operating efficiency and economy in their history, during 1928. This increased operating efficiency took place in the face of reduced traffic during the

(1) This question runs as follows : « Improvements in the steam locomotive. Increased pressures and higher superheats. Improvements in the design of superheaters and parts connected with superheating. Feed water heating and air preheating. Improvement of valve gears. »

first ten months of the year 1928, notwithstanding that the Railroads, particularly since 1923, have made rapid strides each year in improving their methods of operating in order to obtain adequate and dependable transportation.

Fewer trains and locomotives in proportion to the amount of traffic hauled were required in 1928 than ever before. The average load per train was the highest ever reported, having been 2.6 % greater in the first ten months of 1928 than in the same period in 1927.

The distance traveled each day per freight train averaged 307 miles, an increase of approximately 20 % over that for 1923 when the average was 259 miles.

The number of tons of freight moved one mile by a train per hour was greater in 1928 than ever before.

Freight traffic in 1928 was hauled with the greatest conservation of fuel ever reported, coal consumption per 1 000 gross ton miles having been 125 lb. compared with 129 lb. in 1927.

The building of compound locomotives was practically discontinued in the U. S. A. prior to the period of this report and we will therefore consider, with one or two exceptions referred to in the text, only single expansion locomotives.

Questionnaires soliciting information necessary to make a complete report on the general question were forwarded to Railroads of both North and South America affiliated with the Association. Advantage has been taken of suggestions from many sources and I wish to take this opportunity of expressing my sincere appreciation of this valuable assistance.

PART I.

Increased pressures and higher superheats.

Results.

1. A substantial increase in gross ton miles per train hour, which is a good measure of railroad operating performance.

2. Development of locomotives producing greater power per unit of total weight.

3. Increasing capacity of locomotive at all speeds. The mean effective pressure in the cylinders determines the capacity of the locomotive if there is available a sufficient amount of superheated steam and the higher the superheat and the initial boiler pressure the higher the mean effective pressure and the more efficient and powerful the engine will be.

4. Material reduction in steam rate per indicated horsepower.

The majority of new locomotives in all classes of service constructed during this period have had boiler pressures ranging from 210 to 250 lb. per square inch. At the present time there are not less than 1 500 locomotives carrying boiler pressures of 225 lb. and upwards; more than 50 of these have pressures between 265 and 284 lb. per square inch.

There are no indications that the use of higher boiler pressures has resulted in any appreciable increase in maintenance cost nor has there been any material change in design of boiler fittings which can be attributed primarily to increased pressures.

Higher superheats have been coming into use and are being demanded by Railroad Mechanical Departments in practically all cases where new designs are being considered.

A boiler pressure lower than 225 lb. per square inch is an exception in the case of modern locomotives, the general practice being to design for a pressure of 240 to 250 lb. Although the higher pressures are generally used in conjunction with the limitation of maximum cutoff of steam to cylinders, a large number of locomotives, particularly for passenger service, have recently been built without cutoff limitations and with boiler pressures of 225 to 240 lb. per square inch.

One Railroad has had considerable experience during the past three years with pressures from 250 to 300 lb. The experience of that Road so far as maintenance of staybolts, flues, boiler sheets, etc. is concerned has been entirely satisfactory, although an additional period of service will be necessary for determinate conclusions. This increase in pressure and corresponding higher superheat temperatures has had no bad effects on valves, cylinders or rod packing.

The practice of limiting the maximum cutoff of steam to the locomotive cylinders has been a most important factor in a general increase in boiler pressure. The limited cutoff locomotive has, in general, been designed to produce tractive effort equal to the unlimited cutoff locomotive by increasing the boiler pressure rather than by increasing the diameter of the cylinders.

This practice dates back to 1916 when one of the railroads built a 2-cylinder freight locomotive of the Decapod or 2-10-0 type. This locomotive carried 250 lb. steam pressure and steam was cut off from the cylinders at a maximum of 55 % of the stroke. Both road and stationary plant tests were made of the locomotive and to date approximately 600 locomotives of this type are in service on that railroad. During 1925, one of the locomotive builders designed and built a sample locomotive of the 2-8-4 type for fast freight service. This locomotive carried a boiler pressure of 240 lb. per square inch and operated with a maximum cutoff of steam to the cylinders at 60 % of the stroke. Subsequently, 300 locomotives of this and a similar design having 2-10-4 wheel arrangement have been placed in service on various American railroads.

Use of alloy steels. — Two Canadian roads are doing considerable development work in connection with the use of alloy steels in the construction of high pressure boilers. One has 40 locomotives and 12 additional on its subsidiary line in which use is made of silicon steel for the construction of the boilers. This steel shows an average tensile strength of about 76 800 lb. and a yield point of about 46 100 lb. The use of this steel has permitted an increase of boiler pressure from 200 to 250 lb. with little change in design, size or weight.

Similar results are obtained by these roads with 44 locomotives using 250 lb. pressure in which the boiler shells are constructed of nickel steel. This steel shows an average tensile strength of 76 700 lb. with a yield point of 59 200 lb. This represents a gain in strength of about 29 % as compared with the carbon steels usually employed.

It is evident that the use of alloy steel and steel stays will contribute to the successful use of pressures within the foregoing range in conventional stayed type boilers.

Steam temperatures that represent from 250 to 300° F., or more, of superheat are at present, in America, considered good practice. Many locomotives are operating with steam temperatures above 700° F., and a few, with temperatures between

1. Theoretical ratio $\frac{M.E.P.}{B.P.}$ vs. piston speed. Cole's ratio.
2. Actual ratio $\frac{M.E.P}{B.P.}$ vs. piston speed 482.
3. Actual ratio $\frac{M.E.P.}{B.P.}$ vs. piston speed 464.

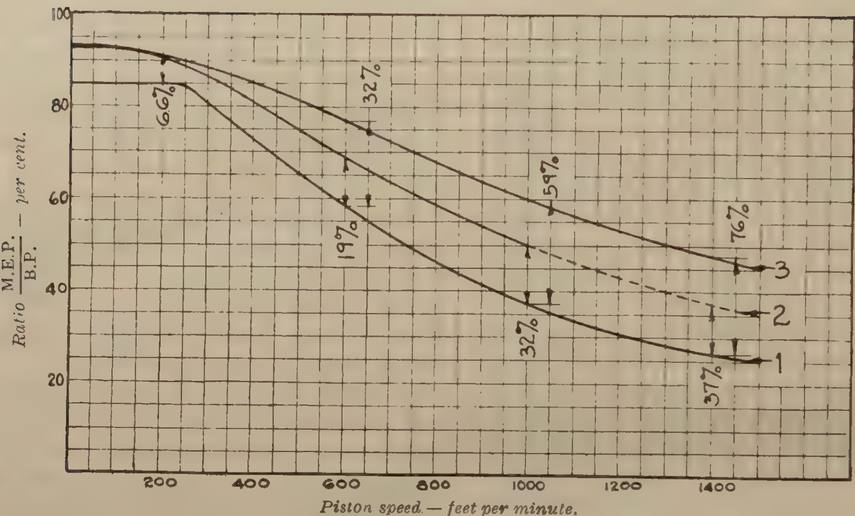


Fig. 1. — Speed factors for superheated locomotive.

4-6-4 type locomotive.
Cylinders = 25″ × 26″.
Diameter of drivers 79″.
Boiler pressure 225 lb.

1. Tractive force vs. speed, calculated.
2. Tractive force vs. speed, test.
3. Cylinder H.P. vs. speed, calculated.
4. Cylinder H.P. vs. speed, test.
Curves 1 and 3 calculated from Cole's ratio.

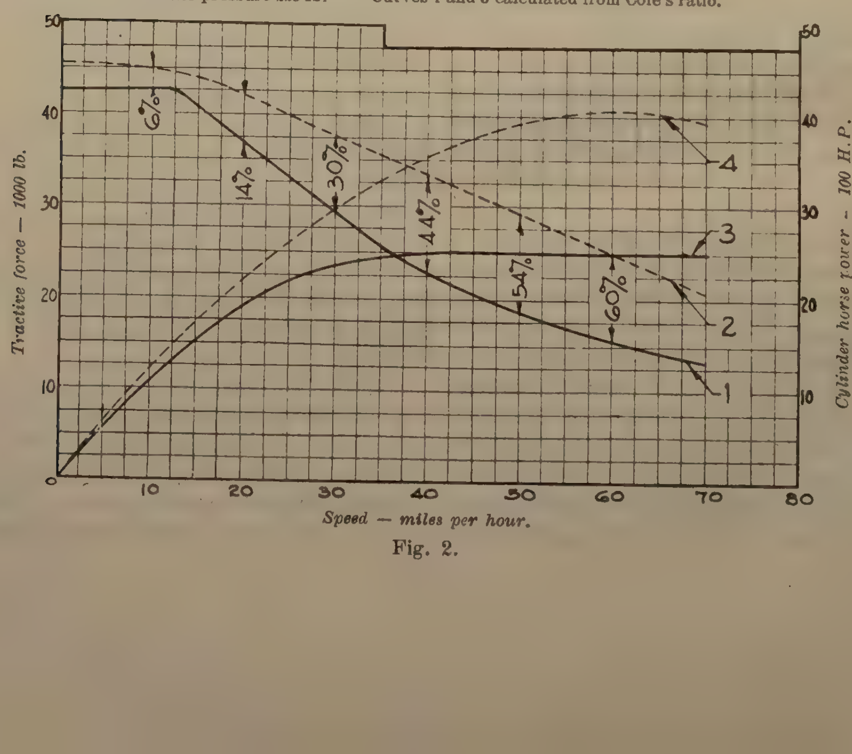


Fig. 2.

800 and 825° F., representing approximately 400° of superheat, when working under normal full load conditions.

In freight service, locomotives being built at present frequently show an increase in gross ton miles per train hour of as much as 75 % over locomotives they replace and similar increases are made with new passenger and switching locomotives. It is to be concluded that this increase in ton miles per train hour is largely due to the greater sustained boiler capacity in relation to the tractive effort that modern locomotives have been designed for. This permits a greater speed, higher power output and more intensive utilization of the hauling capacity.

Figure 1 shows improvement which has been made in the ratio between M.E.P. and the boiler pressure. This ratio plotted against piston speed is usually called the « speed factor ».

Figure 2 shows the comparison between calculated and actual tractive effort and cylinder horsepower (calculated figures based on Cole's ratio).

PART II.

Improvements in the design of superheaters and parts connected with superheating.

Prior to the advent of the type « E » superheater, the type « A » was in general use. There was no other type in service except a very few smokebox superheaters built prior to 1915 which were not changed to the fire tube type.

The type « A » superheater, more generally referred to in Europe as the Schmidt superheater, is of the fire tube type and the type « E » superheater which was developed in Europe is a modification of the type « A ». The type « E » will be referred to in the following text as the improved type superheater.

Due to the ever increasing demand for locomotive capacity as well as the trend toward higher degree of superheat, the use of the improved type superheater has shown a marked increase. The majority of the various designs of locomotives constructed during the last few years have been fitted with the improved type.

There are 49 000 locomotives in America equipped with fire tube superheaters of which more than 1 800 have the improved type. Of the total number fitted with superheaters approximately 25 500 were built with superheaters and 23 500 were saturated steam locomotives converted to superheaters.

Attention is directed to the following test results, from which it is evident that with the improved type superheater, sustained capacity at high speeds is increased 20 tot 25 % over that obtained with the type « A » superheater. For large modern locomotives it is possible to apply an improved type superheater and produce these results without increasing the weight of the locomotive to any great extent providing the boiler is properly proportioned. In the interest of permissible locomotive weights alone the necessity for and the advantages of the improved type superheater are apparent. From tables I and II may be noted that most of the recently constructed, high capacity locomotives are equipped with the improved type superheater.

A discussion of the boiler is incomplete without reference to the superheater. The importance of highest sustained superheat is well known. There has been no device or feature of design added to the locomotive, up to the present, that has had such a beneficial effect upon

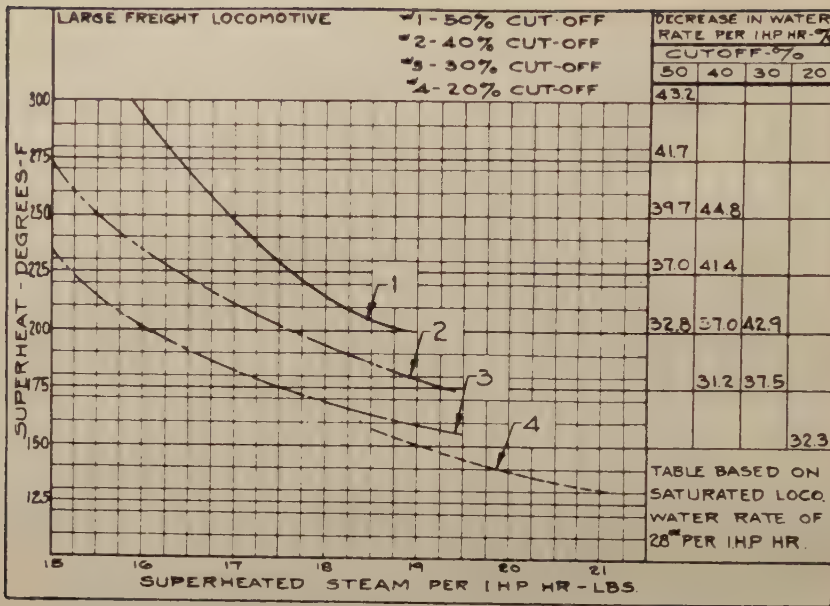


Fig. 3. — Reduction in steam consumption due to increase in superheat.

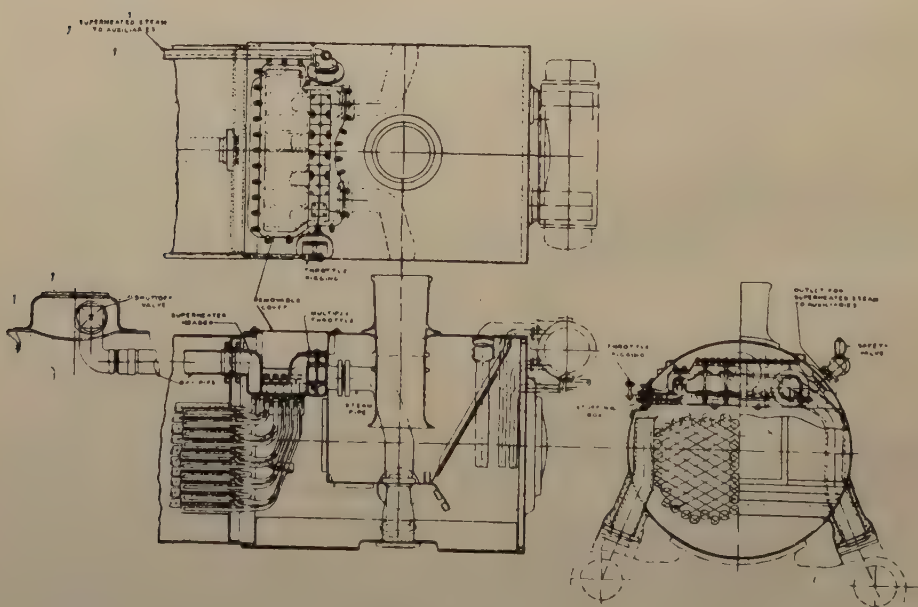


Fig. 4.

locomotive efficiency, as superheated steam. This has been proved so many times by numerous tests throughout the world that it is accepted among engineers as implicitly as the law of gravitation. However, the fact that cylinder efficiency increases as the temperature of the steam increases, even beyond those temperatures that have been common practice, does not seem to be well understood.

The effect of increased superheat on steam consumption is shown clearly by the various curves in figure 3 taken from tests, and illustrates that increasing the superheat follows the law of increasing return.

The production of high superheat on the modern locomotive has been made more and more difficult, by radical changes in the boiler proportions of very large engines, and it has become necessary for the designer to meet these conditions by enlarging superheater capacity. This has been done by increasing the superheating surface, the necessity of which is made clear by the following :

1. — Less heat is left in the gases entering the flues, due to greater heat absorption in large fireboxes, which decreases the heat available for superheating. The use of feed water heaters and exhaust steam injectors, by reclaiming heat that would otherwise be lost, reduces the rate of firing required and naturally decreases the amount of heat offered to the superheater and flues.

2. — On extremely large locomotives, the steam space in the boiler has been substantially decreased. The steam liberating surface has also decreased in proportion to the total amount of water delivered to the boiler. Both of these conditions have contributed to a marked increase in the amount of water carried over by the steam from the boiler to the superheater. Since as much heat is required to evaporate 1 % of moisture as to add 17° superheat to steam, to provide adequate superheating capacity is a difficult task, as steam may carry 5 % or more of moisture when it enters the superheater units. This condition not only points to the necessity for a large superheater but to the importance of proper handling of the water level on the road.

3. — The increased demand for trains operating at higher speeds, requiring more steam for a given size of locomotive, requires superheaters of greater capacity, in order that these demands on the boiler may be met without too serious a sacrifice of boiler effeciency and evaporating capacity. The greatest possible total steam area thru the superheater is also very important as it will result in less pressure drop. The result of this condition has led to the development of a somewhat different arrangement of the superheater previously referred to as the improved type.

The improved type superheater (fig. 4) is distinguished :

1. By the use of one loop (two pipes) in one flue.

2. By the use of flues that are 3, 3 1/4 or 3 1/2 inches in diameter.

3. By the use of superheater tubing 1 1/8 or 1 3/16 inches in diameter.

4. By a layout of superheater flues occupying nearly the whole flue sheet area.

5. By having a larger number of units than other designs.

6. By two units being united, ahead of the front tube sheet, and joined to the header by a single pair of subheaders with ball joint construction. This group is called an « assembly » and is applied and removed as a single unit.

TABLE 1. — Locomotive and bo

1	Railroad	Pennsylvania.	New York Central.	Chesapeake & Ohio.	Missouri Pacific.	Omaha.	Lima
		1	2	3	4	5	6
2	Class or type	2-8-0	2-8-0 G-5	2-8-2 K-2	2-8-2	2-8-2	A-
3	Year built	...	1911	1912	1925	1926	19
4	Boiler pressure (lb. per sq. inch)	205	200	170	200	200	23
5	Cylinders, diameter and stroke (inches)	22×28	23×32	29×28	2-23×32 1-23×28	27×32	28×
6	Diameter of drivers (inches)	56	63	56	63	63	6
7	Weight on drivers (lb.)	173 200	216 000	244 500	244 500	...	248
8	Total weight of engine (lb.)	194 200	243 000	322 000	340 000	...	385
9	Tractive power (lb.) — $\left(\text{T.P.} = \frac{0.85\,D^2SP}{W}\right)$	42 250	45 800	60 800	65 700	63 000	69
10	Boiler, inside diam, 1st course (inches)	78 1/2	80	82	88	84 1/2	86 1
11	Boiler, outside diam., large course (inches)	69 1/2	83 1/4	96	92 15/16	96	94
12	Length over tube sheets (feet and inches)	13′-9 1/2″	15′-0 1/2″	19′-0″	19′-0″	19′-0″	20′-
13	Combustion chamber, length (inches)	...	...	...	40	21	...
14	Grate area (square feet)	49.2	56.5	66.7	66.8	70.3	10
15	Tube and flue heating surface (sq. feet)	2 677	2 766	3 740	3 437	4 020	4 78
16	Firebox heating surface (sq. feet)	166	212	311	363	299	34
17	Total evaporative heating surface (sq. feet)	2 843	2 978	4 051	3 800	4 319	5 12
18	Superheater heating surface (sq. feet)	...	580	832	1 051	2 000	2 15
19	Firebox volume (cubic feet)	222.38	272	404	390	385	46
20	Net gas area thru boiler (sq. feet)	6.1	7.52	9.34	8.81	9.91	10.0
21	Type of superheater	...	A	A	A	E	E
22	Steam area through superheater (sq. inches)	...	38.73	41.0	51.3	70.51	71.9
23	Cylinder horsepower, Cole's formula	1 785	1 904	2 576	2 856	2 624	3 25
24	Max. indicated H. P. obtained on test		...	...	3 176	...	3 70
25	Max. evap. calculated (Cole's formula)	36 295 1 036	40 410	52 848	52 966	60 665	71 34
26	Max. evap. obtained on test	25 896	..	...	61 680	...	...

ensions (14 February 1928).

& North Western.	Atchison, Topeka & Santa Fe.	Pennsylvania.	Pennsylvania.	Texas & Pacific.	Chicago, Burlington & Quincy.	Baldwin Locom. Works (60 000).	Great Northern.	Chesapeake & Ohio.	Denver & Rio Grande.	Denver & Rio Grande.
7	8	9	10	11	12	13	14	15	16	17
-8-4	2-10-2	I-1-S	I-1-S	2-10-4	2-10-4	4-10-2	2-8-8-2	2-8-8-2	2-8-8-2	4-8-2
927	1913	1916	1922	1927	1927	1925	1925	1926	1927	1926
240	170	250	250	250	250	350	210	225	240	21 0
7×32	28×32	30 1/2×32	30 1/2×32	29×32	31×32	1-H.P. 2-L.P. 27×32	4-28×32	4-23×32	4-26×30 4-26×32	2-25×30 1-25×28
63	57	62	62	63	64	63 1/2	63	57	63	67
53 500	248 900	342 050	352 500	300 000	353 820	338 400	510 000	508 000	559 500	288 000
97 000	295 900	371 800	386 100	448 000	512 110	457 500	578 000	574 000	649 000	417 000
75 540	63 500	90 000	90 000	83 000	90 500	82 500	142 000	113 590	131 800	73 300
86	79 3/16	82 1/2	82	86 1/2	90	81 3/8	100	92	100 15/16	90 1/4
94	91 9/16	93	93	98	104	94	109	104	110	104
20'-0"	21'-0"	19'-1"	19'-1"	21'-6"	21'-6"	23'-0"	24'-0"	24'-0"	24'-0"	19-'6"
..	...	42 1/4	42 1/4	42	51	...	72	74	72 1/2	60
100.3	58.5	70	70	100	106	82.5	108	112.9	136.5	95
4 460	4 175	4 044	4 486	4 643	5 445	4 420	6 705	5 982	6 548	4 586
406	193	290	287	537	445	772	421	467	715	509
4 866	4 368	4 334	4 773	5 180	5 890	5 192	7 126	6 449	7 263	5 095
2 131	851	1 479	1 820	2 100	2 487	1 357	1 920	1 801	2 160	1 511
479	278	364	364	589	...	683	...	737	1 009	609
10.22	9.22	10.1	9.43	9.46	11.1	9.375	13 51	11.85	13.25	11.7
E	A	A	E	E	E	A	A	A	A	A
1.92	36.84	54.7	61.5	64.87	78.26	57.0	77.54	68.4	84.4	72.96
3 150	2 400	...	...	3 780	4 320	4 110	5 930	4 280	5 840	3 555
...	...	3 486	3 863	4 200	...	4 515	...	...	...	...
1 390	48 800	55 360	66 121	80 613	84 370	79 590	79 600	75 610	94 630	72 410
...	...	58 301	64 656	...	...	...	...	...	...	...

TABLE 1. — Locomotive and

1	Railroad	Lehigh Valley.	New York Central.	New York, New Haven & Hartford.	Canadian Pacific.	Erie.	
		18	19	20	21	22	
2	Class or type	4-8-2	L-2	4-8-2	4-8-2	2-8-4	4
3	Year built	1923	1925 1926	1928	1914	1927	1
4	Boiler pressure (lb. per sq. inch)	200	225	265	200	250	
5	Cylinders, diameter and stroke (inches)	3-25×28	27×30	3-22×30	23 1/2×32	28 1/2×32	2-2 1-2
6	Diameter of drivers (inches)	69	69	69	70	70	
7	Weight on drivers (lb.)	246 500	244 000	260 000	192 000	275 000	35
8	Total weight of engine (lb.)	369 000	364 000	379 000	286 000	448 000	49
9	Tractive power (lb.) — $\left(T.P. = \frac{0.85\, l^2 SP}{W}\right)$	64 700	60 000	71 000	42 800	70 400	96
10	Boiler, inside diam, 1st course (inches)	82 1/2	82 7/16	79 5/8	72	90	
11	Boiler, outside diam., large course (inches)	96	94	93	80 1/2	100	
12	Length over tube sheets (feet and inches)	21′-0″	20′-6″	19′-8″	20′-8 1/2″	21′-0″	2
13	Combustion chamber, length (inches)	52	51	...	...	...	8
14	Grate area (square feet)	84.3	75.3	70.8	59 6	100	10
15	Tube and flue heating surface (sq. feet)	4 337	4 097	3 633	2 716	5 251	5
16	Firebox heating surface (sq. feet)	392	356	458	316	380	
17	Total evaporative heating surface (sq. feet)	4 729	4 453	4 091	3 032	5 631	5
18	Superheater heating surface (sq. feet)	1 249	1 985	1 756	790	2 480	2
19	Firebox volume (cubic feet)	543	482	...	...	512	
20	Net gas area thru boiler (sq. feet)	10.0	9.71	8.5	6.46	11 42	1
21	Type of superheater	A	E	E	A	E	
22	Steam area thru superheater (sq. inches)	57.0	63.5	59.93	36.4	78.97	78
23	Cylinder horsepower, Cole's formula	3 370	2 950	3 460	1 990	3 650	4
24	Max. indicated H. P. obtained on test	3 035	3 800	...	...	...	4
25	Max. evap. calculated (Cole's formula)	60 360	64 647	65 153	42 575	78 661	90
26	Max. evap. obtained on test	...	...	...	...	...	

National.	Northern Pacific.	Pennsylvania.	Santa Fe.	Canadian Pacific.	New York Central.	Pennsylvania. 1737.	New York Central.	Horatio Allen.	J. B. Jervis.	Pennsylvania.
24	25	26	27	28	29	30	31	32	33	34
-8-4	4-8-4	4-8-2 M-1	4-8-4	4-6-2	4-6-2 K-2	4-6-2 K-4	4-6-4 J-1	2-8-0	2-8-0	2-8-0 H-8-S
927	1926	1926	1-19-27 9-19-28	1926	1911	1913	1927	...	...	...
50	210	250	210	250	200	205	230	350	400	205
2×30	28×30	27×30	30×30	23×32	22×28	27×28	25×28	23.5×30 41×30	22 1/4×30 38 1/2×30	25×28
73	73	72	73	75	79	80	79	57	57	62
000	260 000	273 500	...	183 900	173 000	202 880	182 000	298 500	295 000	219 900
000	426 000	383 100	...	306 500	271 000	309 140	343 000	348 000	336 500	249 500
800	57 500	64 500	66 000	45 000	29 200	44 500	43 300	70 300	70 800	49 200
7/8	82 7/16	82 1/4	86 3/8	78 1/2	70 5/8	78 1/2	82 7/16	61 7/8	61 7/8	76 3/4
90	94	96	99 15/16	88	78 5/8	89	87 5/8	...	...	83 3/4
1'-6"	21' 0"	19'-1"	21'-0"	18'-0"	21'-5 1/2"	19'-1"	20'-6"	15'-0"	15' 0"	15'-1"
8 1/2	74 1/2	98	44	27 9/16	...	...	...	...	...	...
4.3	115	69.9	108.4	66.87	56.5	69.3	81.5	71.4	82.0	55.34
815	4 133	4 302	5 129	3 005	3 553	3 729	4 211	1 413	1 904	2 840
437	485	395	541	297	231	307	281	1 187	1 217	187
252	4 618	4 697	5 670	3 302	3 784	4 036	4 492	2 600	3 121	3 027
840	1 965	1 630	2 426	864	700	1 172	1 965	579	700	600
445	654	518	631	...	320	427	372	...	...	223
.18	9.45	9.71	11.05	7.91	6.65	9.13	9.66	6.76	7 43	7.76
E	E	E	E	A	A	A	E	Coil.	Coil.	A
57.1	64.16	56.1	77.56	45.6	31.89	45.6	64.2	46.2	55.9	41.0
925	2 960	3 280	3 405	2 380	1 745	2 685	2 580	...	...	2 308
300	...	3 621	...	...	...	3 184	4 295	...	...	1 830
000	72 135	60 242	86 174	45 794	41 500	50 070	61 776	...	...	39 787
...	...	72 520	...	...	...	65 400	...	..	...	33 955

27	Railroad	Pennsylvania.	New York Central.	Chesapeake & Ohio.	Missouri Pacific.	Omaha.	
		1	2	3	4	5	
28	Class or type	2-8-0	2-8-0 G-5	2-8-2 K-2	2-8-2	2-8-2	[illegible]
29	Weight on drivers per Ind. H. P. actually obtained on test (7 : 24).	...	...	...	77.2	...	[illegible]
30	Total weight of engine per Ind. H. P. actually obtained on test (8 : 24).	...	...	...	107	...	
31	Max. Ind. H. P. per 1 000 lb. tractive effort (24 : 9) 1 000.	...	...	...	48.3	...	[illegible]
32	Weight on drivers per 1 000 lb. tractive effort (7 : 9) 1 000.	4 100	4 720	4 025	3 720	...	3
33	Total weight of engine per 1 000 lb. tractive effort (8 : 9) 1 000.	4 590	5 300	5 280	5 170	...	5
34	Grate area, sq. feet per 1 000 lb. tractive effort (14 : 9) 1 000.	1.165	1.236	1.095	1.107	1.115	1
35	Grate area, sq. feet per max. Ind. H. P. (14 : 24).	0.0476	...	...	0.0214	...	0
36	Grate area, sq. feet per total evaporative heating surface (14 : 17).	0.0173	0.019	0.0165	0.0176	0.0163	0
37	Grate area per sq. foot of tube and flue heating surface based on 20 ft. 0 in. O. T. S.	0.01268	0.0153	0.0169	0.01845	0.0166	0.0
38	Firebox volume, cubic feet per 1 000 lb. tractive effort (19 : 9) 1 000.	5.26	5.94	6 65	5.93	6.11	[illegible]
39	Firebox volume, cubic feet per max. Ind. H. P. (19 : 24).	0.215	...	...	0.123	...	0
40	Firebox volume, cubic feet per sq. foot of grate area (19 : 14).	4 52	4 82	6.06	5.84	5.475	4
41	Firebox volume, cubic feet per sq. foot net gas area (19 : 20).	36.5	36.1	43.3	44.2	38.9	4.
42	Firebox heating surface, sq. feet per sq. foot grate area (16 : 14).	3.38	3.76	4 65	5.44	4.25	3
43	Net int. gas area, sq. feet per 1 000 lb. tractive effort (20 : 9) 1 000.	0.1445	0.164	0.1535	0.134	0.157	0.
44	Net int. gas area, sq. feet per maximum Ind. H. P. (20 : 24).	0.0058	...	...	0.002775	...	0.0
45	Net int. gas area, sq. feet per sq. foot actual tube and flue heating surf. (20 : 15).	0.00281	0.00272	0.00249	0.00256	0.00246	0.00
46	Net int. gas area, sq. feet per sq. foot tube and flue heating surf. based on 20 ft. 0 in. O. T. S.	0.00157	0.00203	0.00237	0.00243	0.00233	0.00
47	Net int. gas area, sq. feet per sq. foot of grate (20 : 14).	0.124	0.134	0.140	0.1318	0.141	0.
48	Total evaporative heating surf., sq. feet per 1 000 lb. tractive effort (17 : 9) 1 000.	67.4	65.0	66.6	57.7	68 6	[illegible]
49	Total evaporative heating surf., sq. feet per max. Ind. H. P. (17 : 24).	2.71	...	...	1.195	...	1.
50	Total evap. heating surf., sq. feet per sq. foot of grate area (17 : 14).	57.95	52.7	60.8	56.9	61.5	51
51	Total evap. heating surf., sq. feet per sq. foot of firebox heating surf. (17 : 16).	17.1	14.05	13.0	10.5	14 45	15
52	Superheater heating surf., sq. feet per sq. foot total evaporative heating surf. (18 : 17).	...	0.195	0.205	0.277	0.463	0

& North Western	Atchison, Topeka & Santa Fe.	Pennsylvania.	Pennsylvania.	Texas & Pacific.	Chicago, Burlington & Quincy.	Baldwin Locom. Works (60 000).	Great Northern.	Chesapeake & Ohio.	Denver & Rio Grande.	Denver & Rio Grande.
	8	9	10	11	12	13	14	15	16	17
4	2-10-2	I-1-S	I-1-S	2-10-4	2-10-4	4-10-2	2-8-8-2	2-8-8-2	2-8-8-2	4-8-2
	...	98.25	91.3	71.5	...	75.0	...	...	...	...
	...	106 5	100	106.8	...	101.5	...	...	...	...
	...	38.8	42.9	50.6	...	54.7	...	...	...	...
50	3 920	3 800	3 914	3 620	3 909	4 100	3 590	4 480	4 240	3 920
50	4 670	4 125	4 290	5 400	5 658	5 530	4 075	5 050	4 920	5 695
303	0.922	0.779	0.779	1.205	1 171	1.00	0.76	0.995	1.037	1.295
.	...	0.02005	0.01815	0.0238	...	0.01825	...	...	...	...
206	0 0134	0.01618	0.01465	0.0193	0.018	0.0159	0.0152	0.0174	0.0188	0.0186
241	0.0147	0.01645	0.0148	0.0231	0.0209	0 0214	0.0193	0.0226	0.0251	0.0202
34	4.375	4 04	4.04	7.1	...	8.29	...	6.49	7.65	8.3
.	...	0.1042	0.0942	0.1401	...	0.151	...	...	...	...
78	4.75	5.2	5.2	5.89	...	8.28	...	6.55	7.4	6.41
.8	30.2	36	38.6	62.2	...	73.0	...	62	76.0	52 0
05	3.3	4.14	4.11	5.37	4 2	9.36	3.09	4.14	5.24	5 36
355	0.145	0 112	0.1048	0.114	0.1228	0.1135	0.0953	0.104	0.1005	0.1595
..	...	0.00289	0.00244	0.0025	...	0.00207	...	...	...	...
2295	0.00221	0.0025	0.0021	0.00204	0.00204	0.002121	0.00202	0.00198	0.00202	0.00256
2295	0.00232	0.00238	0.00195	0.002181	0.00219	0.002441	0.00242	0.00238	0.00243	0.00249
102	0.157	0.1445	0 1348	0.0946	0.1048	0.1136	0.125	0.105	0.097	0.123
.25	68.8	48.1	53	62.5	65.08	63.0	50.2	56.8	55.1	69.4
..	...	1.242	1.235	1.235	...	1.148	...	...	...	...
.5	74.6	61.9	68.3	51 8	55.6	62.9	65.9	57.5	53.2	53 6
95	22.7	14.9	16.6	9.65	13.22	6.725	16.95	13.9	10.15	10.0
375	0.195	0.342	0.381	0.405	0.423	0.261	0.27	0.280	0.298	0.297

Table 2. — Locomotive and

27	Railroad	Lehigh Valley.	New York Central.	New York, New Haven & Hartford.	Canadian Pacific.	Erie.	
		18	19	20	21	22	
28	Class or type	4-8-2	L-2	4-8-2	4-8-2	2-8-4	4
29	Weight on drivers per Ind. H. P. actually obtained on test (7 : 24).	81.3	64.3	...	...	...	7
30	Total weight of engine per Ind. H. P. actually obtained on test (8 : 24).	121.5	95.8	...	...	...	
31	Max. Ind. H. P. per 1 000 lb. tractive effort (24 : 9) 1 000.	46.9	63.3	...	...	...	5
32	Weight on drivers per 1 000 lb. tractive effort (7 : 9) 1 000.	3 810	4 060	3 660	4 475	3 910	3
33	Total weight of engine per 1 000 lb. tractive effort (8 : 9) 1 000.	5 710	6 060	5 340	6 675	6 375	5
34	Grate area, sq. feet per 1 000 lb. tractive effort (14 : 9) 1 000.	1.3	1.255	0.9975	1.39	1 42	1
35	Grate area, sq. feet per max. Ind. H. P. (14 : 24).	0.0278	0.0198	...	...	...	0.
36	Grate area, sq. feet per total evaporative heating surface (14 : 17).	0.0178	0.0169	0.0173	0.0197	0.0178	0
37	Grate area per sq. foot of tube and flue heating surface based on 20 ft. 0 in. O. T. S.	0.0204	0.01887	0.0192	0.0227	0 0199	0.
38	Firebox volume, cubic feet per 1 000 lb. tractive effort (19 : 9) 1 000.	8.39	8 04	...	...	7.27	9
39	Firebox volume, cubic feet per max. Ind. H. P. (19 : 24).	0.179	0 127	...	...	...	0.
40	Firebox volume, cubic feet per sq. foot of grate area (19 : 14).	6.44	6.4	...	...	5.12	8
41	Firebox volume, cubic feet per sq. foot net gas area (19 : 20).	54 3	49.6	...	...	44.8	7.
42	Firebox heating surface, sq. feet per sq. foot grate area (16 : 14).	4.65	4.725	6.475	5.3	3.8	5
43	Net int. gas area, sq. feet per 1 000 lb. tractive effort (20 : 9) 1 000.	0.1545	0.1616	0.1198	0.1505	0.1625	0.
44	Net int. gas area, sq. feet per maximum Ind. H. P. (20 : 24).	0.00329	0.00256	...	...	...	0.0
45	Net int. gas area, sq. feet per sq. foot actual tube and flue heating surf. (20 : 15).	0.0023	0.00237	0.00234	0.00238	0.00217	0 0
46	Net int. gas area, sq. feet per sq. foot tube and flue heating surf. based on 20 ft. 0 in. O. T. S.	0.00241	0.00243	0.0023	0.00246	0.0027	0.
47	Net int. gas area, sq. feet per sq. foot of grate (20 : 14).	0.1185	0.1289	0.12	0.1085	1.42	0.
48	Total evaporative heating surf., sq. feet per 1 000 lb. tractive effort (17 : 9) 1 000.	73 0	74.3	57.6	71.0	80.2	6
49	Total evaporative heating surf., sq. feet per max. Ind. H. P. (17 : 24).	1 56	1.17	...	...	...	1.
50	Total evap. heating surf., sq. feet per sq. foot of grate area (17 : 14).	56.2	59.25	57.75	51	56.31	5
51	Total evap. heating surf., sq. feet per sq. foot of firebox heating surf. (17 : 16).	12 1	12.52	8.925	9.6	14.81	9.
52	Superheater heating surf., sq. feet per sq. foot total evaporative heating surf. (18 : 17).	0 263	0.435	0.429	0.261	0.44	0.

s (14. February 1828). *(Continued.)*

National.	Northern Pacific.	Pennsylvania.	Santa Fe.	Canadian Pacific.	New York Central.	Pennsylvania. 1737.	New York Central.	Horatio Allen.	J. B. Jervis.	Pennsylvania.
	25	27	26	28	29	30	31	32	33	34
-4	4-8-4	4-8-2 M-1	4-8-4	4-6-2	4-6-2 K-2	4-6-2 K-4	4-6-4 J-1	2-8-0	2-8-0	2-8-0 H-8-5
	...	75.5	...	...	...	63.75	42.3	...	...	120
.	...	105.8	...	...	...	97.1	80	...	...	136
.	...	56.2	...	...	...	71.6	98.9	...	...	37.2
50	4 525	4 230	...	4 080	5 920	4 550	4 200	4 250	4 160	4 460
25	7 410	5 930	...	6 820	9 280	6 950	7 925	4 950	4 750	5 060
85	2.00	1.085	1.64	1.485	1.935	1.56	1.88	1.015	1.16	1.122
.	...	0.0193	...	...	...	0.0218	0.019	...	...	0.0302
198	0.0249	0.0149	0.0191	0.0201	0.0149	0.0172	0.0182	0.0274	0.0264	0.01825
238	0 0292	0.0155	0.0222	0.0205	0.0170	0.0176	0.0199	0.0379	0.0322	0.01465
85	11 38	8.04	9.58	...	10.95	9.6	8.6	...	...	4 56
..	...	0.143	...	. .	...	0.134	0.0868	...	...	0.122
20	5.69	7 42	5.82	...	5.67	6 18	4.55	...	...	4.03
.4	69.2	53.4	57.2	...	48.2	46.8	37.2	...	...	28 75
.2	4.22	5.65	4.98	4 34	4 08	4.43	3.35	16.65	14.85	3.38
144	0.1641	0.1505	0.1674	0.176	0.2275	0.205	0.222	0.0961	0.105	0.1575
..	...	0.00268	...	...	...	0.00286	0.00225	...	...	0.00423
0215	0 00229	0.00225	0.00215	0.00263	0.00187	0 00244	0.00229	0.00478	0.00391	0.00273
0232	0.0024	0.00215	0.00225	0.00236	0.00201	0.00234	0.00235	0.00359	0.00292	0.00205
097	0.0821	0.139	0.1017	0.1185	0.118	0.1318	0.1185	0.0947	0.0907	0.140
.0	80 3	72.75	.	73.5	129 5	90.5	103.5	36.9	44.2	61.6
..	...	1.295	...	...	...	1.265	1.045	...	...	1.655
.5	40.2	67.2	52.3	49.5	67	58.3	55	36.4	38.1	54.75
73	9.525	11.87	10.5	11.15	16.5	13.1	15.95	2 17	2.57	16.2
432	0 426	0.35	0.428	0.261	0.185	0.291	0.438	0.222	0.224	0.198

In addition to the increased capacity made possible by the improved design, the smaller ratio of gas area to heating surface, or what is usually termed the « mean hydraulic depth » of each individual flue, contributes to an increase in the efficiency of heat absorption and results in a reduction in the temperature of gases leaving the flues. Furthermore, the uniform arrangement of the small flues and the proportions of the superheater provide an even distribution of the gases

The use of a smaller diameter flue in the improved arrangement becomes desirable with increased steam pressures. The large flues used with type « A » design require greater thickness for pressures above 200 lb. per square inch, increasing the weight and cost of flues, and reducing the gas area. The smaller diameter flues used with the improved superheater are advantageous because the wall thickness required for even the higher pressures is much less than the larger flues and contributes toward obtaining a larger gas area thru the boiler.

A free upward circulation of water immediately in front of the firebox tube sheet results from the use of one size of flue and from the large space between the swedged-down portions of all flues. This freer circulation tends to prevent scale accumulation at this very effective portion of the flue.

The opening thru the smokebox over the header is provided with a cover which is easily removed and provides access to the unit-bolt nuts for tightening. When the multiple throttle header is used, the opening over the header is somewhat larger. There is, however, no difference in fitting the covering for the opening between the normal header and the throttle-header.

The ordinary methods in roundhouse and shop for maintaining superheater units and their allied parts makes the maintenance of the improved superheater quite simple.

Absence of the damper is characteristic of the improved superheater, for the following reasons :

1. The smaller diameter flue results in a lower gas temperature at the rear return bend of the units.

2. With the improved superheater occupying a much larger area in the front tube sheet and with the lower rows of units well below the center line of the boiler, the application of a damper would be difficult.

3. With the general increase in the use of a throttle between superheater and steam chest, opportunity is afforded for protecting the units by providing a flow of steam thru the units when the throttle is closed, particularly with the blower on.

Results obtained with engines fitted with improved superheater. — The characteristics of the improved superheater have given very satisfactory results in service tests. Figure 5 will prove interesting because the tests plotted were conducted with three engines which differed only in the fact that the first engine had no superheater, the second a type « A » and the third an improved superheater. The lower curve shows the performance of the engine equipped with an improved superheater. Here the minimum coal consumption came down to 2.05 lb. per indicated horse power-hour at approximately 1 300 H. P. and the maximum output of the locomotive was more than 2 100 H. P.

Figure 6 shows the result of tests conducted, during 1923 and 1924, on some

Curve 1. — Locomotive No. 3162, saturated.
Curve 2. — — 318, type « A » superheater.
Curve 3. — — 2997, type « E » superheater.

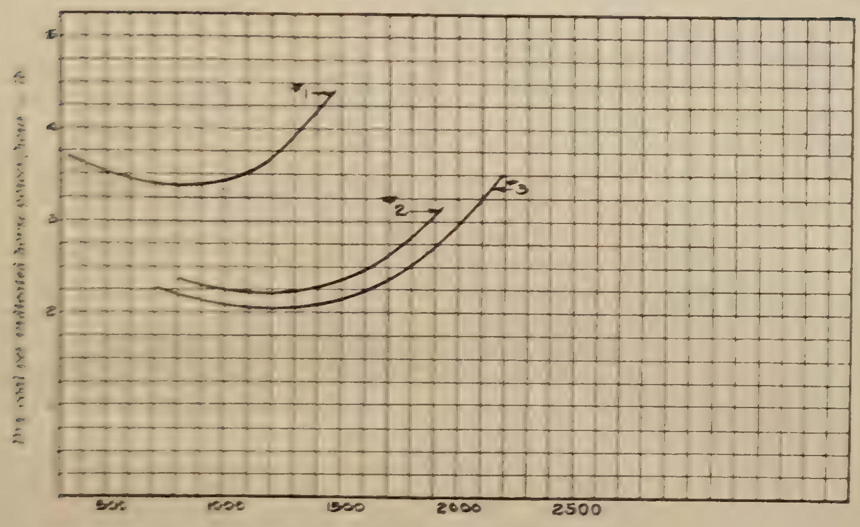


Fig. 5.

Curve 1. — Locomotive No. 790 with injector (Bulletin No. 32), type « A » superheater.
Curve 2. — — 4358 with injector (Bulletin No. 32), type « E » —
Curve 3. — — 4358 with feed water heater (Bulletin No. 32), type « E » superheater.
Curve 4. — — 790 with injector (T. S. Co's sheet L-783) type « A » —

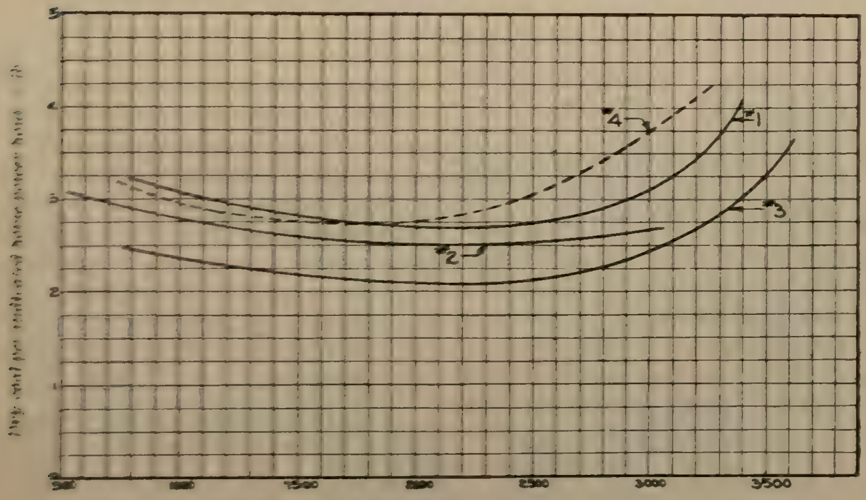


Fig. 6.

larger and more modern locomotives. Curve 1 on this diagram shows the performance of one of these engines having a type « A » superheater, while curve 2 shows the performance of an identical engine with an improved superheater. It will be noted that the fuel economy is pronounced throughout the entire range of power developed on the test.

Figure 7 indicates the boiler efficiency obtainable by the improved superheater on the same locomotives referred to in figure 6. Curve 1, figure 7, is the boiler efficiency of a locomotive with a type « A » superheater and Curve 2 of the same class of engines with an improved superheater. Both were for tests in which the live steam injector was used.

Figure 8 shows boiler efficiencies plotted against equivalent evaporation for a large number of tests of several different locomotives. All the curves, except 1 and 8, show the performance of engines with improved superheaters. It will be noted that the general average efficiency of the boiler equipped with this superheater is very good.

On the question of capacity, the curves in figure 9 show the drawbar horsepower and drawbar pull developed by two identical high-speed passenger locomotives, except for the fact that one had an improved type and the other a type « A » superheater. The full line shows the performance of the type « A », while the dotted line shows the improved type. The added capacity afforded by the latter is very clearly shown.

Figure 10 shows the drawbar horse power of high capacity fast freight engines. The engines designed to take the improved superheater weighed 5 000 lb. less on drivers, yet developed 30 % more power at higher speed than a previous design of the same class and size of engine.

Parts connected with superheat.

Various other parts of the locomotive have been improved in conjunction with the application of superheaters. The rapid introduction of the multiple throttle built integral with the superheater header can quite properly be called an improvement connected with a superheater application.

More than 1 000 locomotives have been fitted with the multiple throttle the use of which is increasing very rapidly. There is quite general acceptance of the idea that the throttle valve should be located between the superheater and the steam chest. The benefits accruing from such an arrangement on a locomotive are that the throttle and its operating rigging are removed from inside of the boiler and naturally made accessible with less difficulty. The handling of the locomotive is improved as the control of the steam is much closer to the steam chest valve and this advantage in handling is particularly noticeable for freight and passenger train service. To build a throttle integrally with superheater header has many admitted advantages in weight, space required, number of steam pipe joints in the smokebox, and, in the form of the multiple throttle, provides a valve, which, being smaller in diameter, remains tight, is easily inspected, manipulated and maintained, and, by providing opening in series of the several valves, permits a closely graduated flow of steam.

The increasing use of superheated steam for auxiliary apparatus on the locomotive has been very noticeable. The location of throttle between superheater and steam chest, above referred to, has

1. Locomotive No. 790 with injector (Bulletin No. 31) type « A » superheater.
2. — No. 4358 — — No. 32) — « E » —

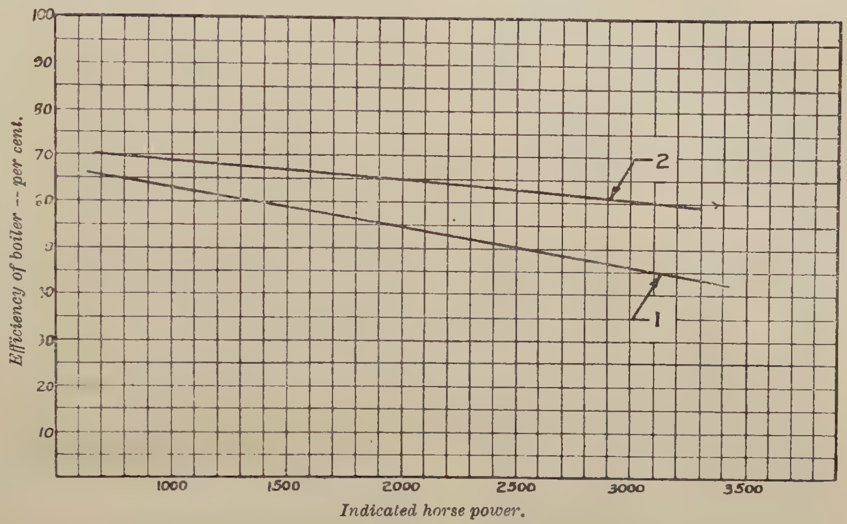


Fig. 7.

No. 1.	Locomotive No.	790	I-1-S.	Type « A »	injector — Pennsylvania.	
2.	—	4358	I-1-S.	Type « E »	injector — Pennsylvania.	
3.	—	4358	I-1-S.	Type « E »	feed water heater — Pennsylvania.	
4.	—	7	H-10-A.	Type « E »	feed water heater — New York Central.	
5.	—	7	H-10-A.	Type « E »	injector — New York central.	
6.	—	350	H-10-B.	Type « E »	feed water heater — New York Central (less lower 5 assem.).	
7.	—	350	H-10-B.	Type « E »	feed water heater or inj. — New York Central.	
8.	—	2566	L-1-D.	Type « A »	injector — New York Central.	
9.	—	1	A-1.	Type « E »	feed water heater — New York Central (Dyn. car).	
10.	—	2700	L-2-A.	Type « E »	feed water heater — New York Central (Dyn. car).	

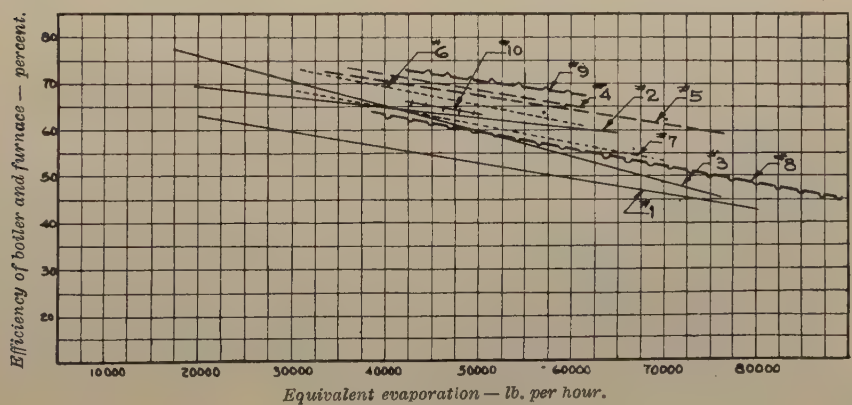


Fig. 8.

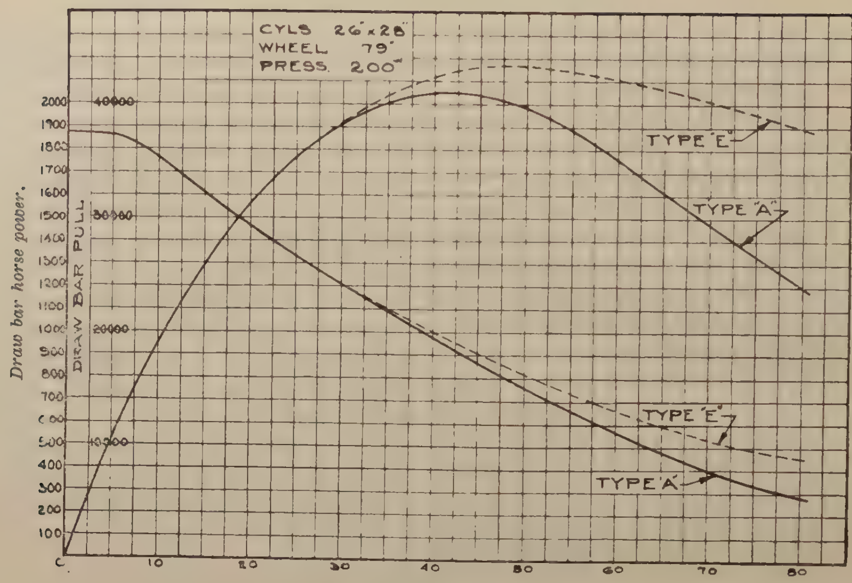


Fig. 9.

CURVE	CLASS ENGINE	CYL.	TRACTIVE POWER	BOILER PRESSURE	WT. ON DRIVERS	DIAM. DRIVERS	MAXIMUM D.B.H.P.	TYPE ENGINE	TYPE OF SUPERHEATER
1&1-A	L1a	28"x28"	54100#	200#	247000#	69"	2710	482	A
2&2A	L2	27"x30"	60525#	225#	242000#	69"	3320	482	E

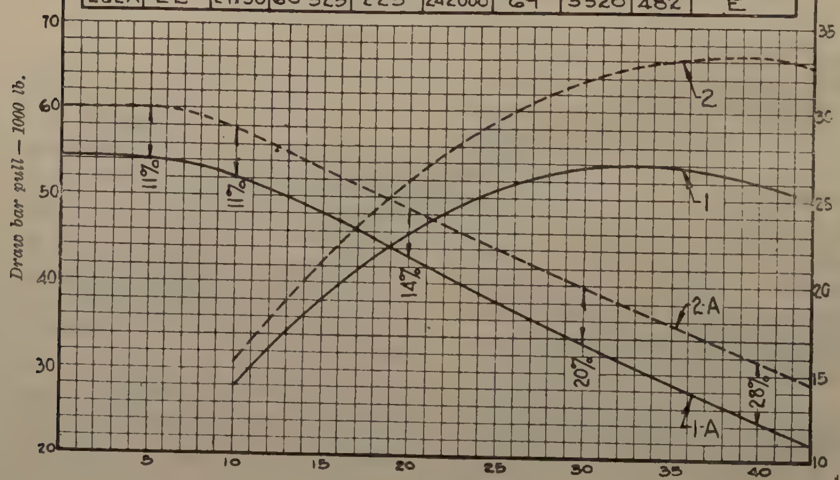


Fig. 10.

made superheated steam easily available for auxiliaries, which are noticeably inefficient in their use of steam. On many locomotives the blower, air and feed water heater pumps, booster, stoker and headlight generator, are all supplied with superheated steam. On nearly all locomotives having a throttle on the steam chest side of the superheater, the blower, even though no other auxiliary is so arranged, uses superheated steam. A steam flow thru the superheater units is thereby provided during the time the main throttle is closed. Both type « A » and the improved superheaters may be arranged so that this economy in the use of superheated steam for auxiliaries may be realized.

Steam driers, separators or de-saturators (all of which are devices for preventing entrained moisture from being carried from the boiler by the steam) have been too infrequently used in America. Probably less than 200 locomotives are equipped with these devices which are of increasing value as our locomotive boilers have increased in size and the amount of steam taken from the boiler per cubic foot of steam space and per square foot of steam disengaging surface (water level area) have increased.

It has been a source of considerable concern that the steam delivered to the superheater contains an unnecessarily high moisture content, necessitating a considerable portion of the superheater being used as a « boiler annex » and naturally requiring much larger superheater than would be the case with dry steam supplied. This is also a very important question and warrants more attention than has been given to it in the past.

PART III.

Feed water heating and air pre-heating.

Pre-heating of boiler feed water with waste exhaust steam is desirable for the modern steam locomotive. The reasons are :

1. On any boiler it increases the maximum evaporative capacity by 12 tot 15 % no matter how efficient the boiler may be in itself.

2. It increases combined efficiency of the boiler by at least 10 % net as it reclaims this amount of heat from the steam exhausted by the cylinders.

3. For equal capacities it makes it possible to decrease the weight of the boiler by 12 tot 14 %.

4. The available supply of water is extended by 15 %.

5. The capital investment will not be any greater for a boiler with a feed water heater than for one having the same capacity without a feed water heater and in most cases the feed water heater equipped boiler will cost less.

6. It slightly increases the cylinder horse power due to lower back pressure on cylinders.

7. It decreases the cost of the boiler maintenance because 15 % of the feed water is returned in the form of condensed steam or distilled water. It also reduces the expansion strains of the boiler, provided the feed water heater is so designed that cold water cannot be pumped into boiler at any time.

8. For a given capacity, it makes it possible to reduce total net weight of engine and tender.

The pump live steam consumption is about 2 % of the boiler evaporation over the usual range of locomotive operation.

There are approximately 5 500 locomotives fitted with various types and designs of boiler feed water heating equipment, both the closed (non-contact) and the open (contact) type of pump driven feed water heaters. Approximately 620 exhaust steam injectors have been applied.

The following outstanding changes in part of the equipment have improved performance :

1. Provision against corrosive water conditions by providing non-ferrous surfaces on the tube plates and substituting non-ferrous for ferrous at the gasket joint.

2. Provision for disposing of the condensate by locating the heater in an elevated position so that condensate is delivered to the tender by gravity.

3. Provision for the removal of oil from the condensate and, at the same time, minimizing the release of steam above the surface of the water in the tender.

4. Further improvement in bringing to the feed water heater all suitable exhaust steam from auxiliaries by means of a single connection, which insures an adequate supply of steam in the heater during the time no exhaust steam from locomotive cylinders is available, and thus making possible the delivery of heated water to the boiler at all times. The advantage of being able to use a feed water heater during drifting, or while standing, and the delivery of heated water during such period, has been more and more appreciated by railroad men.

5. The use of centrifugal feed water pumps instead of the reciprocating pump.

To what extent a feed water heater increases boiler capacity and makes possible saving in engine weight, is readily demonstrated. The following calculation shows the increase in evaporation due to the use of a feed water heater and is based on test data when the boiler was being operated near its maximum.

Boiler pressure	200 lb.
Suction temperature	64° F.
Exhaust pressure	13 lb.
Delivery water temperature	236° F.
Evaporation without feed water heater	42 500 lb.
Heat to be added to 64° F. water to produce 1 lb. of steam at 200 lb. pressure	1167 B. T. U.
Heat to be added to 236° F. water to produce 1 lb. of steam at 200 lb. pressure	995 B. T. U.
$\frac{42\,500 \times 1\,167}{995}$ = 49 800 lb. per hour, less 2 % for steam consumption of pump	48 804 lb. net per hour.

Evaporation with feed water heater. — The results plotted on figure 11 show the increase in evaporative capacity of boiler with feed water heater. Curves A and C were taken from an actual test and B was calculated in accordance with the foregoing method. The evaporation shown on Curves B and C are the net after deducting the steam consumption of the feed pump. Curve A without a feed water heater, shows an evaporation of 42 500 lb. per hour at a coal rate of 120 lb. coal per square foot of grate per hour, while B with a feed water heater, shows a calculated evaporation of 48 800 lb. at the same coal rate. Curve C shows the actual results from test with feed water heater at the same coal rate, and shows

an evaporation of 51 250 lb. per hour. This is a net increase of 20.6 % in evaporation without burning additional fuel. The actual results obtained on test are slightly better than the theoretical.

TABLE III.

Comparison of boiler proportions

of a feed water heater engine vs. a non-feed water heater engine for same evaporating capacity at equal fuel rate.

—	Boiler « A » with feed water heater.	Boiler « B » without feed water heater.
Boiler :		
Pressure	200 lb.	200 lb.
Inside diam., 1st ring, inches	76 1/2	82
Outside diam., 3rd ring, inches	81 1/4	86 3/4
Tubes { number of and diameter, inches	177 2 1/4	209 2 1/4
Tubes { spacing	3/4 inch.	3/4 inch.
Length over tube sheets	20 ft. 0. in.	20 ft. 0. in.
Flues, number of and diameter, inches	40 5 1/2	48 5 1/2
Grate area, sq. feet	52	61.8
Heating surface in square feet :		
Tubes	2 076	2 452
Flues	1 147	1 377
Firebox	229	264
Boiler evaporation at 120 lb. fuel rate without feed water heater	42 500	50 000
Boiler evaporation at 120 lb. fuel rate with feed water heater on boiler « A »	50 000	50 000
Weights :		
Boiler	70 200	81 100
Water	23 100	31 200
Feed water heater and piping (net)	4 000	—
Total	97 300	112 300
Difference in weights of boilers « A » and « B »	...	15 000

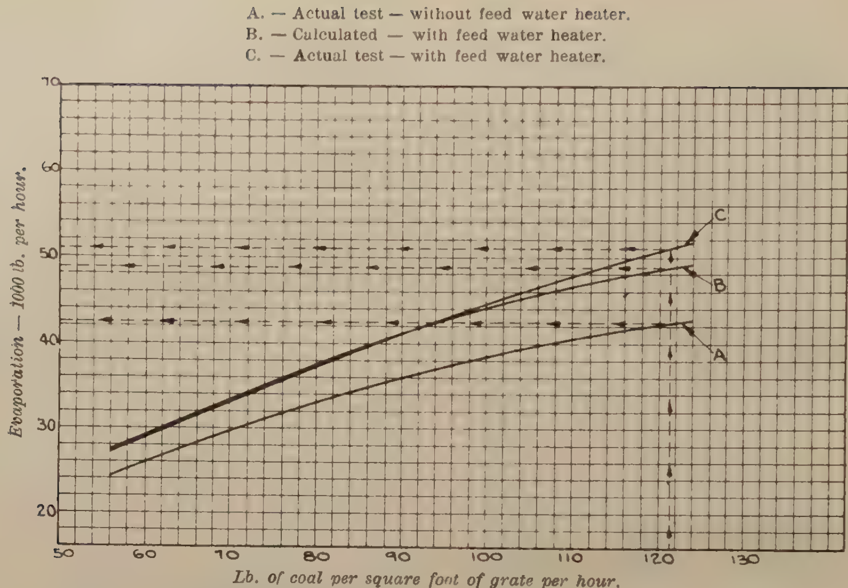


Fig. 11. — Increase in evaporative capacity of boiler with feed water heater.

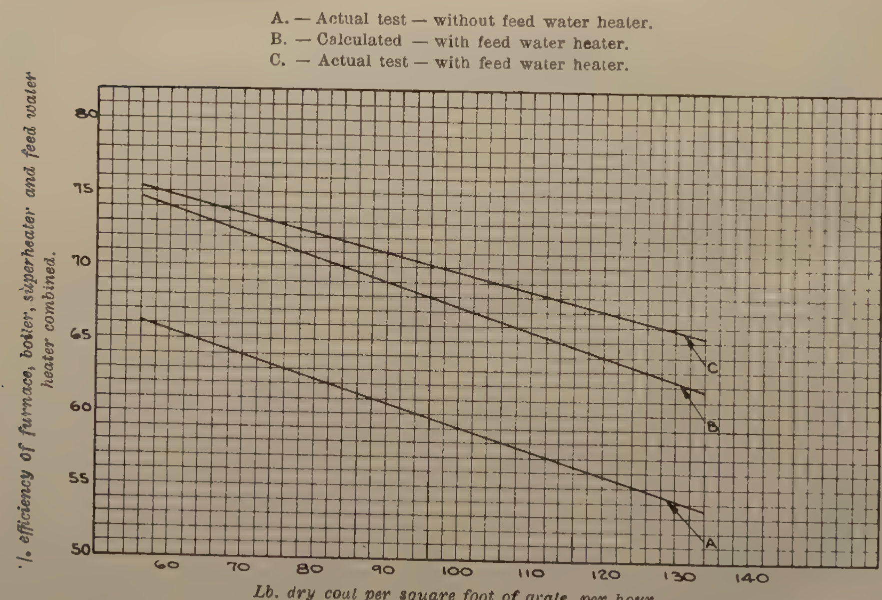


Fig. 12. — Increase in combined efficiency of boiler and feed water heater due to feed water heater.

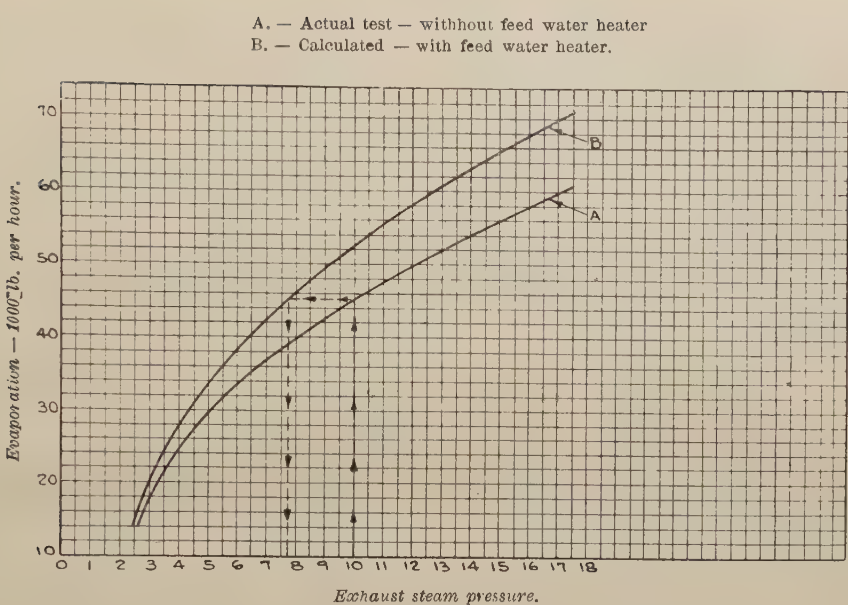


Fig. 13. — Decrease in back pressure with feed water heater.

Table III shows the proportions, according to Cole's ratio, of two boilers, one designed for feed water heater and the other designed for same capacity without a feed water heater, both having a maximum evaporation of about 50 000 lb. per hour with a coal rate of 120 lb. per square foot of grate. In proportioning the non-feed water heater boiler B, it is of course necessary to increase the heating surface, grate area and firebox to maintain the same rate of fuel burned per square foot of grate per hour, as in the feed water boiler. It is noted that the non-feed water heater boiler B must be made 5 1/2 inches larger in diameter and that boiler B will weigh 15 000 lb. net more, than the boiler with feed water heater.

Effect of feed water heater on boiler efficiency. — While the same evaporation is being obtained with boilers A and B, they are burning 120 lb. coal per square foot of grate. In order not to lower the boiler efficiency of B it was necessary as previously stated, to provide a larger grate for boiler B than for boiler A. At this coal rate, the feed water heater boiler with 52 square feet of grate will burn 6 318 lb. of coal per hour, and the non-feed water heater boiler B, with 61.8 square feet of grate, will burn 7 500 lb. of coal per hour. Boiler A, therefore, is using 15.9 % less coal than boiler B. This shows that, in addition to saving 15 000 lb. in the weight of the boiler and water, the feed water heater is effecting a fuel saving of 15.9 %. Figure 12 shows a comparison between the boiler efficiency with and without a feed water heater.

Effect of feed water heater upon back pressure. — Curve A in figure 13 shows the actual evaporation plotted against exhaust pressure for an engine recently

tested. Curve B shows the evaporation with a feed water heater. It will be noticed that at 15 lb. exhaust pressure the evaporation with a feed water heater is increased from 56 000 to 65 562 lb. per hour or a net increase of 17.1 % and that an evaporation of 45 000 lb. per hour will be obtained with 7 3/4 lb. exhaust pressure when a feed water heater is used compared with 10 lb. pressure required for a non-feed water heater boiler.

Air pre-heating.

Air pre-heaters have not yet been applied to locomotives in the U. S. A. In the past, there have been sporadic attempts made to pre-heat combustion air, but, so far as we know, they have not proved successful and the apparatus has been removed.

There is not much question, but that with the further development of the locomotive toward a more thermally efficient machine, air pre-heating will be given further consideration and that such apparatus will be found incorporated in future locomotives. It seems probable, however, that air pre-heating will not make any appreciable progress, so long as the conventional type of locomotive boiler is used. The development of a partial or complete water tube boiler, developing higher steam pressures and higher degrees of superheat will probably be accompanied by some form of air pre-heating apparatus and it is also probable that gas-heated feed water heaters (economizers) will be incorporated in such designs of boilers.

PART IV.

Improvement of valve gears.

Limited cutoff. — The tendency of some locomotive builders and railroads in the United States has been to construct locomotives with a maximum cutoff of 85 to 90 % of the stroke. The shorter cutoff used by European builders necessitated relatively larger cylinders to obtain the desired tractive effort, but so far as we have record, no provision has been adopted by them to improve the starting effort of the short cutoff locomotives.

In 1926, the Mechanical Engineer of the Pennsylvania Railroad, designed, and the Railroad Company built, a freight locomotive in which the maximum cutoff was limited to 55 % of the stroke, to take advantage of the expansive properties of steam.

To furnish adequate starting power at all crank positions there was provided what is termed a starting port in each end of each steam chest bushing. This port was 1/8 inch wide and 1 1/2 inches long, its narrow dimension running longitudinally to the bushing.

The main distribution valve in its central position lapped the starting ports 1/4 inch. These ports were connected with the main ports conveying steam from the chest to the cylinder.

This locomotive was very successful and subsequently the railroad constructed about 600 of them. Within the past three or four years a number of roads have purchased locomotives designed with limited cutoff and equipped with starting ports so that there are about one thousand such locomotives in service in the United States today.

Table IV gives the principal characteristics of the limited cutoff locomotives built in the United States and Canada, using starting ports :

Table IV.

SERVICE.	Type.	Number built.	Cylinders, size in inches.	Boiler pressure. (lb. per sq. inch)	Cutoff. (%)	Tractive effort. (lb.)	Diameter of drivers. (inches)	Weight on drivers. (lb.)	Total weight. (lb.)
Freight.	2-10-0	600	30 1/2×32 30 1/2×32	250 250	55 55	86 500 86 500	62 62	341 000 352 500	371 000 386 100
Switching . . .	0-8-0	90	27×30	250	60	72 700	56	275 000	275 000
Freight.	2-8-4	45	28×30	240	60	66 800	63	248 200	385 000
Passenger . . .	4-6-4	5	25×28	240	65	43 300	75	187 500	353 000
Freight.	2-8-4	20	28×30	240	60	66 800	63	250 200	393 000
Switching . . .	0-8-0	10	23×28	250	65	56 000	51	244 000	244 000
Freight.	2-10-4	12	31×32	250	65	92 700	64	353 800	512 100
Transfer	0-10-0	4	28×30	250	60	76 900	57	340 000	340 000
Freight.	2-8-4	25	28 1/2×32	250	60	69 200	70	275 000	448 000
Freight.	2-8-4	51	28×30	240	60	66 800	63	248 000	388 000
Switching . . .	0-8-0	10	23×28	225	70	51 800	51	252 000	252 000
Switching . . .	0-6-0	50	23×28	205	65	46 000	51	180 000	180 000
Freight.	2-10-4	55	29×32	255	60	81 400	63	300 000	448 000
Switching . . .	0-8-0	15	22×28	250	65	51 300	51	220 000	220 000
Freight.	2-8-4	5	28×30	240	65	69 200	63	248 200	385 000
Freight.	2-8-4	2	28×30	240	65	69 200	63	249 500	383 000
Transfer	0-8-0	1	22×28	250	65	50 400	52	233 400	233 400

The saving in fuel is more pronounced on those classes of locomotives which operate at such speeds that the greatest cutoff difference exists between them and the ordinary locomotive having full gear cutoff. This applies to locomotives in switching and transfer service and also to those used in slow freight service. For locomotives in fast freight, express and passenger service the benefits to be derived from limiting the cutoff are not so great, but on account of the larger cylinder or higher pressure employed there will always be a significant economy in operation, as the limited cutoff engine operates at a shorter cutoff than the conventional locomotive at any speed, and therefore will show economy in fuel throughout the whole range of speeds, or this economy may be translated into additional power at speed if desired, as the limited cutoff locomotive will produce a horse power for a smaller expenditure of steam.

An incidental advantage of the use of limited cutoff is in the wider port openings at the shorter cutoffs which characterize this type of locomotive. This, of course, is a function of the increased steam lap, and is partly responsible for

the improved cylinder efficiency of the limited cutoff locomotive.

Another important advantage of limiting the cutoff is in the smoother torque curve produced by the characteristic overlapping of the cylinder effort at each revolution of the driving wheels. It has been demonstrated that the flattest curve is obtained with the cutoff limited to 50 % of the stroke. It is for this reason that the ratio of tractive effort to weight on driving wheels has been largely increased on limited cutoff locomotives as built in the United States.

The prevailing practice in the United States at the present time is to adopt 60 % cutoff for freight locomotives and 65 % for switchers.

For switching engines which have to start often and accelerate quickly, experience has indicated that 65 % cutoff is preferable. As these engines work habitually with the reserve lever in the corner, the saving in fuel at 65 % cutoff over the usual 90 % makes its adoption a paying investment.

Very few passenger locomotives have been built with limited cutoff, as these locomotives work for such a short period in the longer cutoffs that the fuel saving is not so significant. Experience has, however, demonstrated that the incidental advantages of the limited cutoff, such as higher cylinder efficiency and smoother starting torque with quick acceleration, make is a desirable adjunct of a passenger locomotive.

To restore the power lost by limiting cutoff it is permissible either to increase the diameter of cylinder or raise the working pressure, or both. The prevailing practice in the United States is to raise the boiler pressure, as the loading gauge does not always permit increasing the cylinder diameter. Either of the changes mentioned increases the weight of the locomotive, as higher boiler pressure involves thicker shell sheets and more substantiel bracing and staying, as well as an increase in the strength of the running gear to withstand the augmented piston thrust.

By increasing the cylinder diameter with no change in boiler pressure, the weight of the locomotive is increased about 3 %. If the boiler pressure is increased, but no change made in the cylinder, the weight will be increased about 4 1/2 %. These figures apply where the cutoff is reduced from 90 % to 50 % of the stroke.

The introduction of the limited cutoff locomotive has necessitated the adoption of longer valve travel. All limited cutoff locomotives, with the exception of those built for and by the Pennsylvania Railroad have had a valve travel of from 8 3/4 to 9 inches. Nearly all of these have been equipped with the Baker valve gear. These long valve travels have improved the steam distribution and cylinder efficiency, but the relatively great increase in inertia forces have made it necessary to redesign and strengthen the valve gears and have also brought about some readjustment of power reversing gears to prevent undesirable movement at speed.

A typical valve setting for a road locomotive having 65 % maximum cutoff is :

	Inches.
Valve travel	8 3/4
Steam lap main port	2 1/2
Steam lap auxiliary port . . .	9/16
Lead	1/4
Exhaust lap	1/16

This gives a cutoff for the auxiliary port of 84.7 %. Practically all limited cutoff locomotives for freight or switch-

ing service have an exhaust lap varying from 1/16 to 1/8 inch.

Loco. valve pilot. — The Loco. valve pilot is an indicating and recording device having instrument located in cab of locomotive in front of engineer, the dial of which is calibrated in miles per hour. There are two hands on dial, indicating speed of locomotive and position of cutoff in terms of miles per hour. The speed element is of centrifugal type driven by friction wheel in contact with periphery of driving wheel. The cutoff indicator is actuated by contour of cam, movement of which is controlled by rack and pinion connection to lifting shaft of valve gear. The cam is designed from drawbar pull versus speed curve for locomotive and also compensates for the angularity effect of lifting shaft motion in respect to change in cutoff position. The indication of the cutoff hand on dial gives the proper cutoff position for engine to develop maximum output for that incidental speed with full throttle opening.

When the cutoff hand is immediately beneath the speed hand, that point of cutoff is being used which will give maximum drawbar pull, at that incidental speed. For economy in operation the cutoff hand should be kept as far ahead of speed hand as possible without the speed hand varying. The resultant cutoff will produce maximum fuel economy for that incidental speed, track profile and train load.

Tests of the Loco. valve pilot as applied to a *Mountain* type 4-8-2 wheel arrangement with 69-inch driving wheels, 27 × 30-inch cylinders and 225-lb. boiler pressure shows an average saving of 13.5 % in coal fired per 1 000 gross actual ton miles per train hour, working time. The test runs were made without and with assistance of the device under ordinary operating conditions. The actual gross tonnage of the train ranged from 1 813 to 6 140 averaging approximately 3 530 tons.

Walschaerts — While the Walschaerts valve gear has practically superseded the Stephenson, the basic principle of the gear has not changed from its earliest application and the only changes that may be considered as improvements are in the mechanical construction and design of detail parts such as have been brought about by experience and increasing sizes of locomotives.

Long valve travel. — Naturally the increase in sizes of locomotives and the desirability of having good steam distribution necessitates long valve travel. Six and seven-inch valve travel has been used extensively for freight, passenger and switching locomotives in the past. The valve travel on modern motive power has increased gradually and there are a considerable number of locomotives now operating with a maximum of nine inches. This can be obtained with all modern valve gears.

The 9-inch travel has not been in use a sufficient length of time on passenger locomotives with the Walschaerts gear to determine whether or not it is practicable, due to the acute angles that are set up in the gear on account of the long travel.

While it is not denied that increased port areas are required as the size of the cylinders is increased, it is the writer's contention that this is obtained, in part, at least, by the larger valves used with larger cylinders and that valve travels that result in areas greatly in excess of the cored passages to and from the cylinders are of no advantage and only result in applying an unnecessarily heavy valve gear with its increased possibility of trou-

ble due to the greater inertia stresses and higher rubbing speed.

Variable lead.— While the Walschaerts gear is regularly referred to as a constant lead gear it is sometimes considered advisable on locomotives that do little, if any, backing up with load, such as for thru passenger or freight service, to design the gear for a small lead in full forward motion and increasing lead as the cutoff is shortened.

While this has not been done to a great extent there may be some advantage in this arrangement in the decreased preadmission obtained at starting and long cutoffs.

While a number of mechanical attachments have been designed to obtain this result the usual and least complicated method is to locate the eccentric so that it will subtract lead in forward motion. It is not recommended for switching service or for locomotives that may be called on to work in backward motion, as this will add lead in backward motion.

Some Walschaerts valve gears have been supplied with an additional lever interposed between the radius rod and combination lever and pivoted at the rear end of the back valve chamber head. This arrangement magnifies the motion produced by the link but does not affect the motion produced by the combination lever and affords a longer valve travel than usual with the Walschaerts gear without exceeding the normal limits of angularity. The maximum travel obtained is 9 inches, and in order to take full advantage of this travel and permit finer adjustments of cutoff, the power reverse gear is operated from the cab by a lever and quadrant cut with more than the usual number of teeth.

The inside valve gear for the three-cylinder locomotive which was adopted by the American Locomotive Company after considerable investigation as the most suitable arrangement, was invented by Mr. H. N. Gresley, Chief Mechanical Engineer of the London & North Eastern Railway, England, and the American Locomotive Company holds an exclusive American license for it.

This consists of two transverse levers located in front of the cylinders connected to extensions of the outside valve stems. The long lever except for a small allowance to compensate for lost motion, has arms with ratio of lengths as two to one, the long arm being driven by the L. H. valve gear and the fulcrum or pivot point being rigidly attached to the structure of the locomotive. The two arms of the short lever which is pivoted to the short arm of the long lever are of equal lengths except for a similar allowance for lost motion. The outer end of this lever being driven by the R. H. valve gear, its inner end has a similar but opposite motion except as it is modified by the movement of its pivot point which receives motion from the L. H. valve gear. The resultant motion being similar to that of the outside valves and so timed that with the R. & L. engines connected 120° apart the motion of the inside valve will be correct for the middle engine 120° from the R. & L. engines.

Baker.— On 3 March, 1903, patent was granted on a valve gear which had been used for a number of years on a traction engine. In 1909, using the basic principles of this gear, a locomotive valve gear was developed on which a patent was secured on 14 November 1911.

The first application of the Baker locomotive valve gear was to engine No. 9 on the Toledo Terminal Railroad in 1910.

It was followed in rapid succession by applications on other roads, until now there are in service nearly twelve thousand of these gears.

From 1910 until 1922 this gear remained a standard so far as the gear frame and contained parts were concerned, with the exception of some small constructional features which were made for improvement in design.

In 1922, in order to meet the demand of various railroads for greater horsepower, and consequent reduction in transportation cost without increasing the weight of the locomotive, the Pilliod Company developed what is known as the Baker long travel and long lap gears. These valve gears produce a longer valve travel than valve gears made prior to them which permits the use of a longer steam lap, thereby increasing the port and exhaust opening and decreasing the pre-admission and compression.

The mechanism of this gear in many ways resembles the Walschaerts and like the latter is adaptable to either inside or outside admission. The gear consists of an eccentric crank with its pin and eccentric rod, gear frame, reverse yoke, radius bars, connecting rod, bell crank, valve rod, combination lever and union link, together with the customary reversing and controlling arrangement of reach rods, reverse shaft, reverse lever, etc. The reverse yoke is pivoted in the gear frame and its upper end is attached to the gear reach rod. In the reverse yoke, the radius bars are pivoted. At the lower end of these bars the gear connecting rod is suspended. The connecting rod is attached at its lower end to the eccentric rod and at its upper end to the bell crank, the latter being pivoted to the gear frame. The gear receives its motion from two sources. That derived from the eccentric crank is carried thru the eccentric rod to the connecting rod and thru the connecting rod to the bell crank, and thence thru the valve rod to the combination lever. The lower end of the combination lever is attached to the crosshead thru the union link and from this crosshead movement the lap and lead of the valve is derived. These two motions are thus transmitted, by the combination lever, to the valve. From this it will be seen that the gear frame and contained parts produce the same function that the link support and link of the Walschaerts does; that is, the port opening movement, while the combination lever of both gears act the same.

However, the action of the gear parts of the Baker gear is more rapid than the Walschaerts link, giving a quicker movement to the valve, while the locomotive is passing its dead center, giving to the valve its maximum opening with less piston travel.

The Baker valve gear is one of the first that does not use links and blocks common to other valve gears in the reversing mechanism but is assembled with pins and bushings, which, when badly worn, can easily and quickly be replaced; thus, bringing the gear back to its original position and the valves back to their original setting.

Of the twelve thousand sets of these gears now in service, the applications, with the exception of two locomotives in Russia and ten locomotives in South Manchuria, have been on the North American Continent.

Young. — The Young locomotive valve gear, an outside radial type, was first applied to a Pacific type passenger locomotive, on the Grand Trunk Railroad in December, 1915. The development stage of this device has been sufficiently exten-

ded, therefore, to embody in its design such mechanical refinement as experience has shown necessary for insuring a dependable and durable mechanism that will meet the exacting conditions for modern railroad equipment.

The advantages claimed for the Young gear are capacity for unusually long valve travel without objectionable angles to individual members, late maximum cutoff and, as already mentioned, the elimination of the principal source of lost motion. There have been 513 applications of the Young valve gear, all on the North American Continent, except 18 which were applied to some Central Railway of Brazil engines.

This gear consists of a swinging link on each side of the locomotive with connection thru the crosshead, radius bars with a reverse shaft, and radius bar lifters, combination links, combination levers, valve links and concentric inside and outside rocker shaft.

This gear does not use eccentric cranks, eccentric pin or eccentric rod, but the link is swung by a direct connection to the crosshead. Thus, the valve gear is independent of any wheel connection which is one of the greatest sources of lost motion; therefore, some of the errors in valve adjustment are eliminated.

The Young valve gear has the link on the right side furnishing the constant component motion for the righthand valve and the variable component motion for the lefthand valve, the latter delivered thru the link block, radius bar and rocker shaft to the combination lever on the lefthand side.

A little consideration will show that this valve gear is much like the Walschaerts in principle, but differs in detail in the manner in which the results are accomplished. The cranks of a locomotive are always at right angles, the right side usually leading the left by 90°, while the left side leads the right by 270°. Therefore, this valve gear is mutually dependent for operation upon the crosshead and must be arranged one for direct and the other indirect motion. The reverse shaft has mounted upon it on the righthand side a reverse shaft bell crank which has a bearing on the shaft and a reverse shaft arm keyed to the shaft. There are two reach rods, the upper and lower reach rod. The upper reach rod being attached to the reverse arm keyed to the shaft, while the lower reach rod is attached to the reverse bell crank which has an extension below the center of the reverse shaft, so that when the reverse lever is moved forward, the righthand link block is raised, thus giving an indirect variable component motion to the lefthand valve, while the lefthand link block is lowered, giving a direct variable component motion to the righthand valve.

It will be seen that one radius bar working below the center of the link, while the other radius bar is above the center of the link, compensates for the fact, already mentioned, that the righthand crank leads the left by 90°, while the left leads the right by 270°.

The righthand valve gets its constant component motion from its own crosshead thru the righthand union link, link, combination link and combination lever. Its variable component comes from a link which is swung by the connection from a pin 90° from the righthand crank pin. This motion comes thru the left union link, link, radius bar and outside rocker shaft arm being transferred across the engine thru the outside rocker shaft to the outside right rocker shaft arm. The pin at the upper end of the outside right rock shaft arm forms a moving fulcrum

for the right combination lever and thus the two motions are combined and transmitted to the right valve thru the valve link. Instead of using an eccentric crank, with pin set 90° from the righthand crank, for the source of variable component motion for the righthand valve, as is done with the Walschaerts gear, advantage is taken of the fact that the left crank pin is 90° from the right and thus the variable component for the right valve is brought from the left side in the manner already indicated. The motion to the lefthand valve is obtained exactly as described for the right, except that in the entire discussion the words right and left should be interchanged and the variable component motion is carried across to the left side by the inside rock shaft, instead of the outside rock shaft.

Southern. — The Southern valve gear is a radial type with all parts outside of the locomotive frame. It differs considerably from the Baker and Walschaerts as its motion is derived from only one source, namely, the eccentric crank. The eccentric crank is secured to an extension on the main pin, so that the eccentric crank pin is 90° behind the main pin in forward motion, and 90° ahead for backward motion on inside admission valves, and just the opposite for engines with outside admission valves.

To date the Southern valve gear has been applied to 2 155 locomotives. Of this number thirty were applied to the Paulista Railway (Brazil) and a number to the Queensland Government Railways (Australia).

The eccentric rod leads forward and is supported near its front end by a radius hanger. The upper end of this hanger is pivoted in a link block, which slides in a link, resting on a link support which is secured rigidly to the engine. At the extreme front end of the eccentric rod, the transmission yoke is attached. The upper end of this yoke is connected to the horizontal arms of the bell crank, which is pivoted to the link support. To the vertical arm of this bell crank there is attached a valve rod which leads to the valve. From this it will be seen that the movement of the eccentric crank is transferred thru the eccentric rod, transmission yoke, bell crank and valve rod to the valve. With the link block in its mid position, the maximum movement of the valve is the vertical movement of the back end of the eccentric rod. This eccentric rod is equivalent to a combination lever, as it is so proportioned that the vertical produced by the eccentric crank delivers to the valve a movement equal to twice the sum of the lap and lead. This makes the lead constant for all positions of the reverse lever and for all cutoffs.

As the link block is moved from its central position, the radius hanger connected to the eccentric rods affects the motion of the front end of the eccentric rod increasing the valve travel; this motion being greater when the link block is in one of its extreme positions. When the link block is thrown forward, the combined effect of the arc, which the radius hanger is forced to travel and the motion of the eccentric rod, causes proper oscillation of the bell crank and movement of the valve for forward motion, and when the link block is in its rear position the arc of the radius hanger is reversed, giving backward motion.

From this it will be seen that the rise and fall of the back end of the eccentric rod causes the lap and lead movement, while the horizontal movement of the

eccentric rod produces the port opening travel.

The principal advantages of this gear are a nearly perfect distribution of steam at all points of cutoff, a full port opening with a minimum of the piston stroke and a minimum of wearing parts, there being only eight on each side of the locomotive. The link is stationary and the link block moves only when the engine is reversed, which eliminates practically all wear at this point. The valves on locomotives equipped with this gear are easily squared, as no changes are required to the eccentric rod, radius hanger or transmission yoke. Any shifting of the valve required can be done by altering the valve rod or shifting the link on the link support.

Caprotti-Poppet. — The conventional reciprocating valve is always in motion, although at variable speeds, and, on one side or the other, is constantly engaged in restricting the port opening. Poppet valves, on the contrary, are fixed in their open and closed positions, having movement only at the action points between « open » and « closed » with quick transition from one to the other. With the conventional spool type piston valve, steam distribution is by means of a single valve which controls both inlet and exhaust, thus mechanically binding two separate and distinct phases to the disadvantage of both. Restricted inlet ports restrict exhaust ports and valve designers must carefully « average » these mutual disturbances to obtain approximately correct results. While it is generally recognized that independent exhaust control is a thing to be desired, the resultant complications of double valves and gearing usually react against its employment.

The poppet valve offers a simple means of separating these two phases of steam distribution and, when properly actuated, has numerous other advantages over the sliding valve.

The gear was produced in 1921 by the Italian Engineer, Arturo Caprotti. The *Consolidation* locomotive equipped on the Italian State Railways is today in regular operation and has not been seriously modified from the first design. It has given seven years of satisfactory service. This type of gear has been constructed and applied to approximately 100 locomotives in foreign countries. In the United States two locomotives have been equipped and it is contemplated to equip two more.

Advantages claimed for this type of valve gear are :

1. Fuel, water and oil saving.

2. Development of more mean effective pressure for a given point of running cutoff.

3. Can always be operated at full throttle and cutoffs as close as 10 % can readily be obtained.

4. The valves have a very quick action, which, combined with their « staying » open at full port, reduces wire drawing of steam thru the valves and gives power with economy.

5. The independent action and full opening of the exhaust at all points of cutoff cuts down back pressure and provides a practically constant release. This, together with a controlled compression, makes for long life on rod bushings and keeps down the « pound ». This is particularly advantageous in high-speed, short cutoff service.

6. The valve gear provides an automatic bypass by the action of the valves which

are held open by gravity during drifting. This also is a feature for easy running and keeping down wear.

Test results of the experimental applications made in the United States are not at this time available.

A detail description of the Caprotti-poppet valve gear for locomotives is published in a bulletin issued by the Baldwin Locomotive Works, Philadelphia, Pa., U. S. A.

[625 .614]

REPORT No. 1

(Europe).

ON THE QUESTION OF THE IMPROVEMENTS IN THE PERMANENT WAY EQUIPMENT OF LIGHT RAILWAYS (SUBJECT XVIII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Ed. VAN NOORBEECK,

DIRECTOR OF WAYS AND WORKS
OF THE BELGIAN NATIONAL LIGHT RAILWAYS COMPANY.

Figs. 1 to 21, pp. 2154 to 2197.

On various occasions the International Railway Congress Association has placed on the agenda of its sessions the design of the elements constituting the equipment of railways as regards the formation and the permanent way.

Question XVIII of the Madrid session examines this point of view in all its bearings and its study will make it possible to follow present tendencies in the construction of the permanent way of light railways and to decide the most suitable appliances to be used in making soundly constructed railways from the point of view of first cost and of upkeep in the cost of working.

As a whole the light railways have copied the measures used by the large lines, although the construction and working conditions are often not comparable. We are sorry to see the application pure and simple to light railways of certain methods used on lines carrying heavy and fast traffic, the same as we regret the absence of any extension to the local railways of certain arrangements used on the tramways. At the present time particularly, the light railways find themselves in very difficult economic conditions and should enquire very closely into all details of the track and reduce to a minimum the costs of construction and upkeep.

We wish to thank all the companies who have been good enough to reply to our questionnaire and thereby facilitated our task.

Thiry-three companies have returned the questionnaire duly filled up; these companies work an aggregate of 20 325 km. (12 630 miles).

If several companies have not considered it convenient to answer, this is probably due to their lines being equipped according to the usual practice and because nothing special or new is being tried or has been experimented upon by them.

The maximum gradients as well as the minimum radii of curves are very different according to topographic circumstances, the method of traction and the nature of the traffic.

The maximum gradient rarely exceeds 3 % (1 in 33) exceptionally, and in very

(1) Translated from the French.

special cases, there are heavier gradients; electric traction has often made it possible to work over gradients steeper than the standard.

As regards the radii of curves, the tendency is towards larger radii and these are generally not below 75 m. (3 3/4 chains) for lines of 1.435 m. (4 ft. 8 1/2 in.) gauge and 30 m. (1 1/2 chains) for those of metre gauge. It is advisable, in order to facilitate the extension of light railways, to leave the greatest liberty in the choice of the gauge. Each gauge can be the most suitable in certain local conditions.

Of the thirty-three companies who have replied, eight have the normal gauge of 1.435 m. (4 ft. 8 1/2 in.), seventeen have metre gauge [or 1.067 m. (3 ft. 6 in.)]; two companies use both these gauges; two use gauges of 0.75 m. (2 ft. 5 1/2 in.) and 0.60 m. (2 feet) and finally three use simultaneously gauges varying between 1 m. (3 ft. 3/8 in.) and 0.60 m. (2 feet).

The majority of the lines of the companies referred to are worked by steam. The progress which has been made in the transmission of electric energy is developing electric traction on the light railways. Some companies, particularly in order to reduce their working expenses, are at present experimenting with petrol motor traction.

The average width of the formation varies between 3.80 m. (12 ft. 6 in.) and 4.40 m. (14 ft. 5 in.) for track of metre gauge, and between 4.10 m. (13 ft. 6 in.) and 4.30 m. (14 ft. 2 in.) for track of 1.435 m. (4 ft. 8 1/2 in.). The width of the ballast for metre track varies between 2.90 m. (9 ft. 6 in.) and 3.50 m. (11 ft. 6 in.) with a thickness of 0.30 m. (12 inches) to 0.50 m. (19 11/16 inches). That of the 1.435-m. (4 ft. 8 1/2 in.) lines varies between 4.10 m. (13 ft. 6 in.) and 4.30 m. (14 ft. 2 in.) with a thickness of 0.30 m. (12 inches) to 0.50 m. (19 11/16 inches).

The axle loads of the locomotive stock as well as of the rolling stock is steadily increasing and sometimes reaches 16 tons. These increases in the weights are due to the necessity for providing more powerful locomotives to haul heavier trains and thereby reduce working expenses and also to be able to use carriages of greater capacity which give greater comfort to travellers. These increased loads naturally react on the construction of the formation and of the track.

It is very difficult to maintain the normal profiles in cuttings, the soil of which is bad or normally wet. In such a case it is necessary to arrange for drainage of the formation and, if the sub-soil should be clayey, to use a greater depth of ballast. This sub-ballast is composed of cinders which prevent the rise of the clay. One can also remove the layer of clay and replace it with rubble which then acts as soling for the ballast.

Ballast.

The choice of the ballast employed in the work is very often the result of an economic problem or of special circumstances. In this way we notice the use of sand, cinders, slag, broken stone and gravel.

The requirements for good ballast are: to obtain the maximum adhesion between the sleepers and the ballast, to be well drained in order to preserve the sleepers, and lastly to facilitate tamping and to remain in place so as to ensure good stability.

From this point of view the best ballast is broken stone. Nevertheless, the nature

of the stone should be examined as regards the direct effect of the constituent elements of the rock on the wood or metal and on the fastenings, and their influence on the development of parasites which attack wood.

The choice of the sleeper determines sometimes also the kind of ballast used. For instance, ashes, so to speak, must not be used in conjunction with metal sleepers.

In order to make it easy to examine the state of the permanent way (sleepers and fastenings) a great number of companies keep the sleepers above the ballast, leaving their tops visible; others who have only in view the regular inspection of the fastenings, have limited themselves to keeping the rails and fastenings free from ballast, leaving it, however, on the sleepers.

Opinions on the advantages and disadvantages of these methods are divided.

The partisans of covered sleepers adduce that this cover preserves the sleepers against rotting. In our opinion this argument is of little value, because the perishing of the wooden sleepers is not particularly due to the influence of the surroundings, but more especially to causes inherent in the wood. On the other hand, it is often remarked that the wooden sleepers rot chiefly at the bottom which is in direct contact with the ballast, the latter being insufficiently ventilated.

The uncovered wooden sleepers may, however, be more exposed to the danger of splitting.

In our opinion the system to be preferred is that of keeping the fastenings free, leaving the wooden sleepers covered as much as possible.

Of the answers received, nineteen companies leave the tops uncovered, eight entirely cover their sleepers, two use both systems indiscriminately, and two uncover their sleepers only between the rails.

Rails.

When the rail is quite adequate for the task which it has to perform, there is in the track an element of very great influence both from the point of view of first construction and the upkeep of the line as well as from that of the life of the rolling stock.

For the light railways generally laid on special sites or besides roads, Vignoles rails are almost exclusively used and there exists a tendency to standardise the sections as follows : for lines of 1.435 m. (4 ft. 8 1/2 in.) gauge : height 140 mm. (5 1/2 inches), width 130 mm. (5 1/8 inches) and heads 60 mm. (2 3/8 inches); and for steam operated metre gauge track: height 113 mm. (4 7/16 inches), width 90 mm. (3 1/2 inches) head 45 mm. (1 3/4 inch); and for electrically operated metre gauge track : height 125 mm. (5 inches), width 105 mm. (4 1/8 inches) and head 57 mm. (2 1/4 inches).

Three companies are still exclusively using the bullhead rail fastened to the sleepers by means of chairs. The *French State Railways*, on certain of their narrow gauge lines, also use bullhead rails fastened to the sleepers by cast iron chairs and wooden keys.

The linear weight of the rails varies considerably and naturally depends on the importance and nature of the traffic carried by the line, on the weight of the rolling stock in service and on the kind of traction (for the return current).

The weights of the vehicles have a tendency to grow, the capacity of coaches and wagons increases incessantly, the motive power must, of course, follow if operating expenses are to be kept down.

It is, therefore, advisable to lay down on lines on which an important steam traffic must be expected to materialise, and where electric traction has to be expected, rails of Vignoles section and of a linear weight of at least 32 kgr. (64.5 lb. per yard).

The length of the rails varies between 6 and 18 m. (19 ft. 8 1/4 in. and 59 ft. 5/8 in.) with a tendency towards the latter.

This question of the length of the rails has been examined many times at previous sessions of the International Railway Congress.

In the early days of railways the rails were very much shorter owing to difficulties in manufacture. At the Paris Congress, third session of 1889, it was declared (Report by Mr. Michel on question II, D): « The improvements in the manufacture of steel have permitted the substitution of rails of 5 m. to 6 m. (16 ft. 5 in. to 19 ft. 8 1/4 in.), used up to now, by rails of 9 m. to 12 m. (29 ft. 6 3/8 in. to 39 ft. 4 1/2 in.), which length will no doubt not be exceeded unless one has recourse to special arrangement to allow of free elongation due to changes in temperatures. » (*Bulletin*, issue of July 1889, French edition, 1st part).

At the fifth session in London, 1895, it was said :

« It has been recognized that about 12 m. (39 ft. 4 1/2 in.) constitutes a sufficient length; it must not be less than 9 m. (29 ft. 6 3/8 in.) in order to avoid unnecessary multiplication of the joints and it cannot exceed 15 m. (49 ft. 2 1/2 in.) because the intervals between spaces for elongation become too great; besides handling when laying or renewing would become too difficult if the rails were too long. » (Report No. 1, question II, p. 1232, by Mr. Ast, *Bulletin of the Railway Congress*, French edition, issue of May 1895.)

At the seventh session, in Washington in 1905, it was stated :

« The French Companies and the Belgian State are at the present time having rails of 18 m. (59 ft. 5/8 in.) and exceptionally rails of 22 m. (72 ft. 2 1/8 in.) and 24 m. (78 ft. 9 in.) rolled. No drawback has resulted from the use of these very long rails. They may be a little difficult to carry... It would be possible to go up to 24 m. (78 ft. 9 in.) if there were not the difficulties of transportation. » (Report No. 2 question II, by Mr. Van Bogaert, *Bulletin of the Railway Congress*, November 1904, English edition, pp. 1401 and 1403.)

These different reports deal with full section rails. It is therefore incontestable that progress has been made, and as regards light railways, there is no reason for not using in their construction rails of 18 m. to 20 m. (59 ft. 5/8 in. to 65 ft. 7 3/8 in.). We consider it would be difficult to go farther without employing special mechanical means of laying them, because the maintenance gangs do not have sufficient men to manipulate rails of greater weight.

With the exception of the *Société des Transports en Commun de la Région Parisienne*, few companies have definitely found corrugations in their rails, the great trouble of the tramway lines. In the case of light railway lines the reasons adduced to explain these corrugations are braking and the skidding of the wheels. The first mentioned Company has principally experienced corrugations : 1. on the outer line of rails on curves of large radius; 2. on the straight, alternatively on one side of the rails and the other, on the parts of rails where the coaches are

thrown outwards by oscillating movement. Apart from the company first mentioned above none takes steps to overcome the trouble.

One should, however, draw attention to the report made by the sub-commission which was charged by the International Union of Tramways, Light Railways and Automobile Transport with the study of the very important question of corrugated wear, and which was presented at the XXIst International Congress of the Union held in May 1928 in Rome.

This commission after having studied the phenomenon and determined its causes, has indicated the measures and precautions which should be taken in order to remedy this trouble.

« Rail metal :

« *a*) to improve the quality of the metal, to use only sound and homogeneous steel;

« *b*) to use steel with a large enough tensile strength, and a high limit of elasticity, and the greatest possible percentage of elongation, these different characteristics should be in correct proportion to one another.

« In the present state of our investigation the characteristics of ordinary carbon rail steel which appear to respond best to the above conditions are :

« Tensile strength : 75 to 80 kgr. per mm^2 (47.6 to 50.8 Engl. tons per square inch).

« $R + 6\ A$ greater than 175.

« $\frac{E}{R}$ always greater than 1/2, and as great as possible. »

Twenty-seven companies state that in laying their lines they cant their rails inwards; only six companies do not give any cant to their rails.

Sixteen companies obtain this cant by adzing their sleepers.

One company which uses both Vignoles rails and bullhead rails supplies the information that the cant for the Vignoles rails is obtained by adzing the sleepers and for the bullhead rails by the shape of the chair.

Three companies use both systems indiscriminately.

The reason for this cant as given by several companies is the conical shape of the tyres of the wheels of their vehicles.

No company, except for track laid on highways, reports the use of wooden, felt or cork plates between the supporting chair and the rail. It would, however, be advisable in order to reduce the shocks and vibrations to insert a layer of felt between the rail or the bearing plate and the sleeper. The companies which operate light railways and which use as much as possible large radii for their curves, generally do not make special provision for the laying of these curves. However, some companies with curves of smaller radii than 30 m. (1 1/2 chains) for the metre gauge lines and of 50 m. (2 1/2 chains) for the 1.435 m. (4 ft. 8 1/2 in.) gauge lines use twin Vignoles rails for the inside rail.

Many of the Railway Companies require when their vehicles have to work over private sidings, curves of a minimum radius of 75 m. (3 3/4 chains) for the 1.435 m. (4 ft. 8 1/2 in.) gauge. In order to encourage the establishment of private sidings on their lines the Belgian National Railway Company has authorized, in cases of absolute necessity, of wagons to pass over track with minimum curves of 50 m. (2 1/2 chains) on the following conditions :

The track with a radius of between 75 m. (3 3/4 chains) and 50 m. (2 1/2

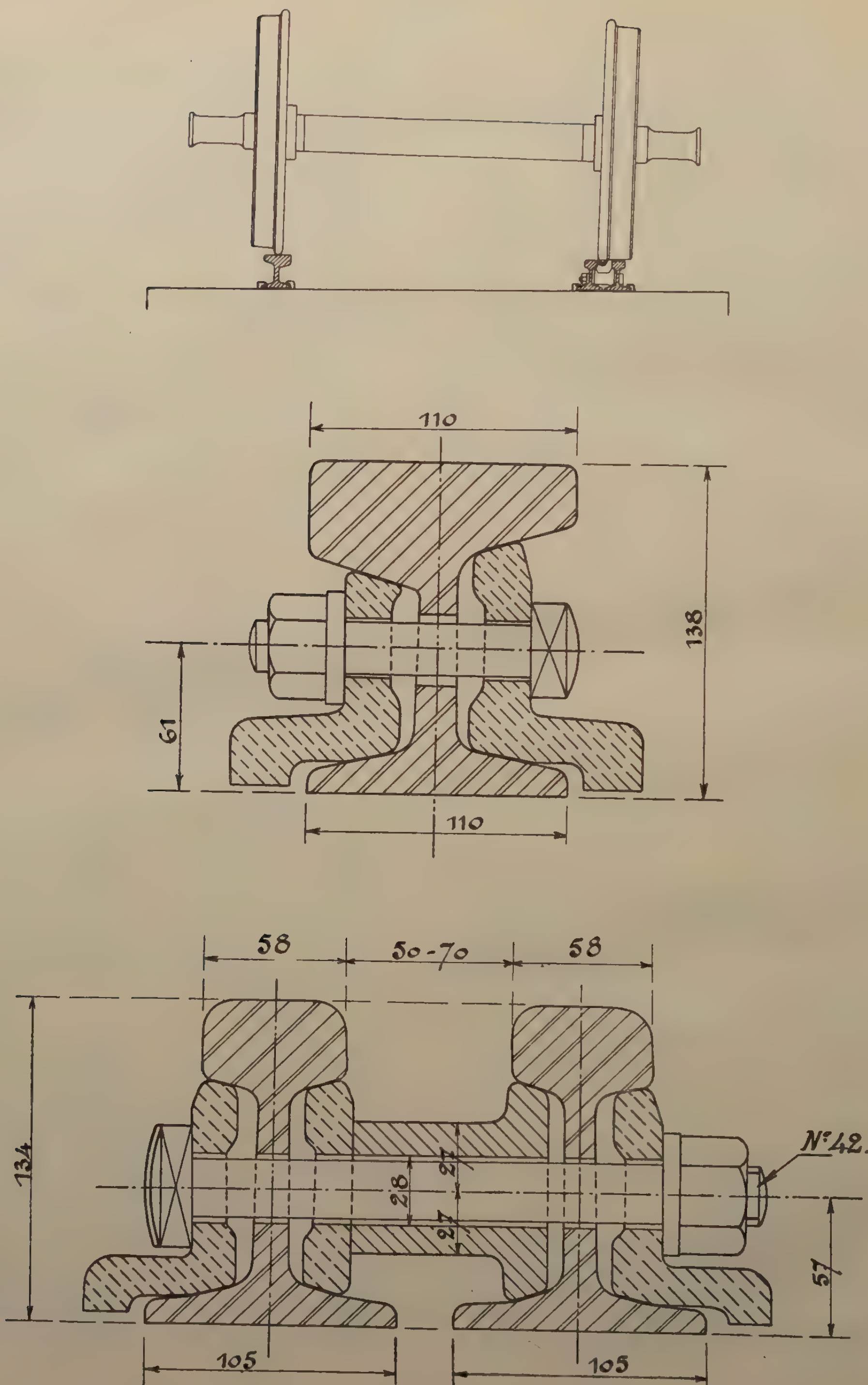


Fig. 1.

chains) will be built in such a manner that the outer wheels of the wagons will not run any more on their flanges but on their treads using a rail of a special section with a very wide head. The inner wheels will be laterally guided. An arrangement fitted at the two ends of the curve allows the passage without shock from the normal running surface to the special surface and vice-versa. It is advisable to pull the wagons through these curves instead of pushing them.

Figure 1 shows the arrangement of this special method of laying.

The *Société nationale des chemins de fer vicinaux* (Belgian National Light Railway Company) has tried this method with very encouraging results.

With track laid on roadways, principally tramways, a similar arrangement is used for curves with small radii; the inner rail consists of a grooved rail or of twin rails and the outer rail is a special rail with a wide groove at the middle of the curve, and inclines at the extremities, so as to meet the bottom of the groove in the rails.

Two companies, the *Chemins de fer secondaires du Nord-Est (Paris-France)* and the *Société nationale des chemins de fer vicinaux (Belgium)* use Barberot keys on their lines laid alongside public roads and on special formation (fig. 2) in the outer line of their metre gauge track in the case of curves of 100 m. to 75 m. (5 to 3 3/4 chains) radius and in those of 150 m. (7 1/2 chains) radius on the normal gauge lines.

In our opinion this practical and cheap arrangement ought to be more generally adopted; it shows excellent results.

The *Société pour les Transports en Commun de la Région Parisienne* and the *Société nationale des chemins de fer vicinaux (Belgium)* have been experimenting with steel rails of high tensile strength for curves of a small radius.

The first of these companies uses in curves with a radius of less than 30 m. (1 1/2 chains) rails made of steel containing 12 % manganese or of nickel chrome steel.

The *Société nationale des chemins de fer vicinaux (Belgium)* uses rails the steel of which, as regards its chemical composition must conform to the following :

Carbon, 0.70-0.85 %;
Manganese, 0.60-0.90 %;
Silicon, 0.20 % maximum;
Phosphorus, 0.04 % maximum;
Sulphur, 0.06 % maximum, and the tests of which give a breaking load of 77.3 kgr. per mm² (49.1 Engl. tons per square inch);
Minimum elongation, 8 %.

No company uses rails which have been heat treated, a process consisting of a rapid cooling of the top part of the rails, so as to obtain the sorbitic structure which is characterised by a fineness of the grain, an increase in the durability, resilience and limit of elasticity. The process can be carried out either at the works before the delivery of the rails or with the rails already placed in position in the track [1].

The object of all these methods is to increase the resistance to wear and to diminish the number of broken rails. The saving to be obtained in this way has attained much greater importance since the war owing to the increase in the cost of the materials and of the labour for upkeep.

(1) For particulars, see the pamphlets published by Mr. Sandberg and the « Forges de Châtillon Company, Commentry et Neuves Maisons », as well as the special reports of the U. S. Steel Products Co.

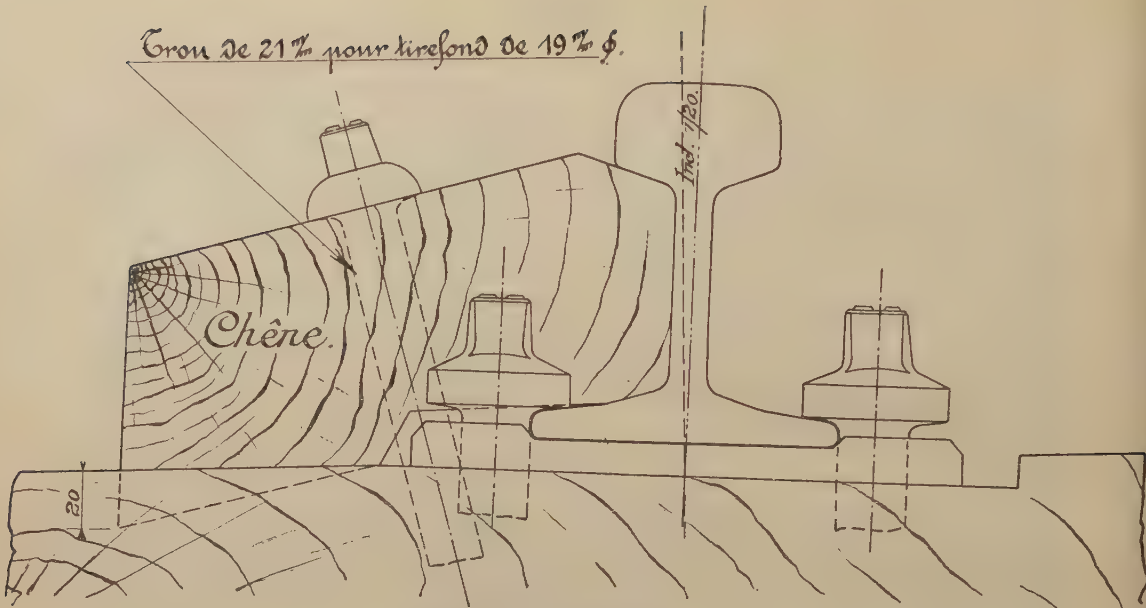


Fig. 2. — « Barberot » key.

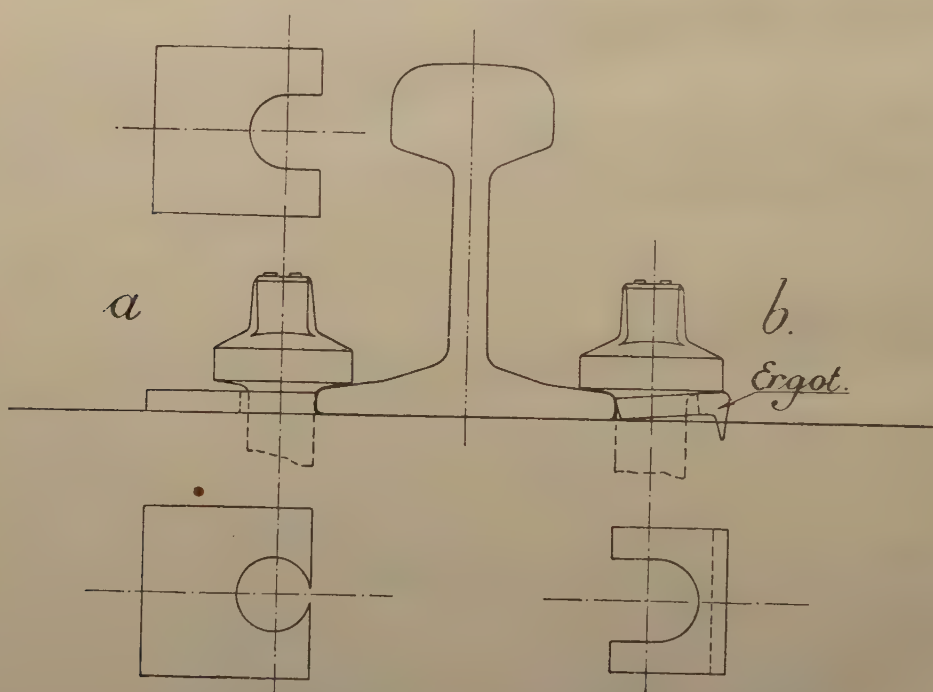


Fig. 3. — « Ramy » stud plates.

Explanation of French terms in figs. 2 and 3 : Chêne = Oak. — Ergot = Fang. — Trou de 21 mm. etc... = Hole of 13/16 inch for coachscrews of 3/4 inch. ϕ.

In a general manner the use of special steels is very limited on account of their prohibitive price. Their utilization is chiefly of value in certain special cases, for example, for lines on curves of small radius and for permanent way details in places subject to great stress.

It is general practice to lay the rails with the joints in line when ordinary fish-plates are used in straight alignment. Eight companies use staggered joints on curves with a radius of less than 100 m. (5 chains).

When rails are welded, there is no general practice as to the position of the joints.

Four companies still fasten down their rails with spikes or with a spike at the outside and a coachscrew on the inside or use spikes on the straight and coach-screws on curves.

As regards the use of sole plates (always of metal), opinions are divided : fifteen companies lay the rails direct on the sleepers whilst fourteen put plates under the rails.

We believe we can summarize the question by quoting the work that has been done by the *Société nationale des chemins de fer vicinaux (Belgium)*. Until the last few years this company used metal sole plates, but it was found that these wore the rail foot very considerably owing to the rubbing of the rail on the plate, which wear was still more accentuated by the presence of dust from the sand or cinder ballast. It was decided to lay a trial length without plates. The result was excellent as regards wear and the vehicles rode better. Unfortunately, the coachscrews which were only 0.019 m. (3/4 inch) diameter with 0.040 m. (1 9/16 inches) width of head had a tendency, particularly in the curves, to bend and break. Tests were then made with the sole plates on curves of less than 200 m. (10 chains) radius and without plates in the other parts of the line, but with coacscrews equipped with shoulder plates Ramy system (fig. 3*a*). This track has behaved very well.

In order to simplify the laying and to remove some of the inconvenience which was caused by the use of the Ramy plate, experiments were made by laying lines on the straight and on large curves without plates, but with coachscrews of 0.024 m. (15/16 inch) diameter with a head of 0.050 m. (2 inches) width. The line stands up well although in certain cases of high speed and heavy trains, a slight bending of the coachscrews is still being noticed.

At present, we are carrying out tests with the following system :

Laying with shoulder plates and locking plate Ramy system (fig. 3*b*), with a coachschrew of 19 mm. (3/4 inch) diameter and 40 mm. (1 9/16 inches) width of head.

A good oak sleeper can be re-bored four times if care is taken to stop up the old holes with oak plugs.

Only one company, the Southern Railway (Great Britain) reports the use of wood treenails in order to increase the life of the wooden sleeper against mechanical wear caused by the fastenings.

It seems, therefore, that the different systems such as treenails (threaded plugs of impregnated hard wood), spiral metallic dowels, and Lakhovsky coachscrews, have not given the results expected.

Joints.

For a long time, railways have shown a tendency to reduce the number of joints, because the weakest point of the track and that which causes most worry to the

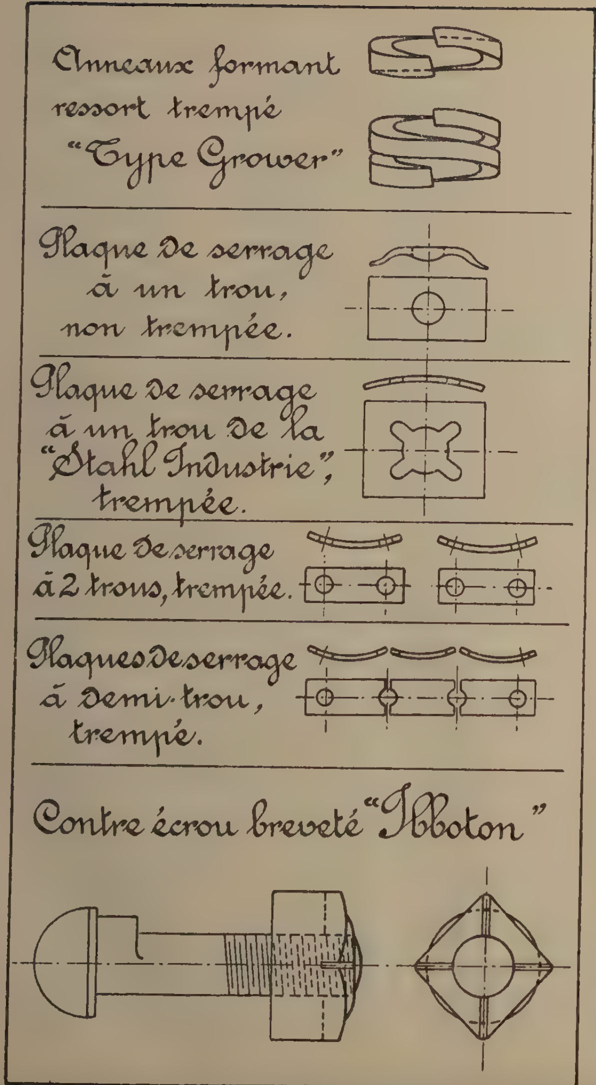


Fig. 4. — Locking devices.

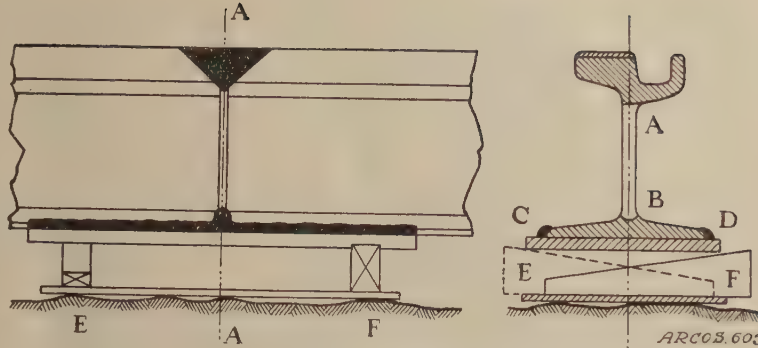


Fig. 5. — « Arcos » joint without fishplates, with welded feet.

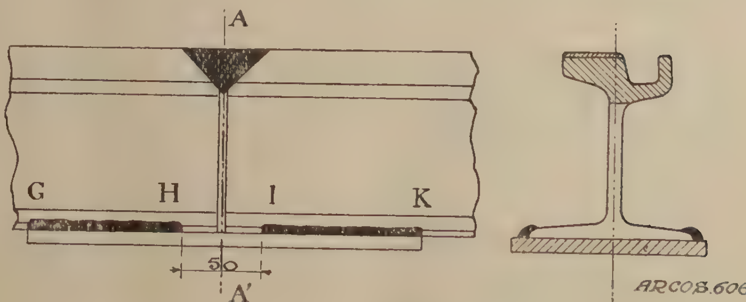


Fig. 6. — « Arcos » joint without fishplates, with non-welded feet.

Explanation of French terms in fig. 4 :

Anneaux formant ressort... = Spring washer, Grover type, single and double coil. — Plaque de serrage à un trou non trempée = Single hole locking plate, not tempered. — Plaque de serrage à un trou de la « Stahl Industrie... » = « Stahl Industrie » single hole locking plate, tempered. — Plaque de serrage à 2 trous = Locking plate with two holes, tempered. — Plaques de serrage à demi-trou... = Locking plates with half holes, tempered. — Contre écrou... = Check nut, « Ibbotson's » patent.

engineer, is undoubtedly the joint. To secure a good joint is the constant care of the permanent way gangs. One must, therefore, pay attention to reducing the number of joints and endeavour to retain the best possible design.

The object in view is a double one : to improve the running of the trains and also to lengthen the serviceable life of the track. An expensive joint is therefore justified if it can fulfil the conditions indicated above.

No subject which concerns the improvement of the track has been more discussed than the fishplates. It is also this vital problem of the track to which inventors have given most attention, the patents dealing with joints being very numerous. Their very variety and complexity show that perfection has not yet been attained and that the ideal would consist in the complete suppression of the joint.

Except on light railways where the moving load is not excessive, the trains are not numerous and the speed low, one must, if one cannot eliminate the joints, use simple fishplates and strengthen and improve them as much as possible.

The general tendency may be summed up by saying that endeavours are being made everywhere to stiffen the joints by bringing the joint sleepers nearer to one another, whilst continuing to use the suspended joint.

As regards the fishplate proper the principle is to make joints as rigid as possible with fishplates having a moment of inertia which approaches that of the rail and perfectly fitting the section of the latter.

Generally, the steel used in the manufacture of fishplates has a lower tensile strength than the rail steel (48-55 kgr. [30.5 to 34.9 Engl. tons per square inch]) and a greater elongation (15-25 %).

During the last few years the most complicated shapes of fishplates have been tried; angle fishplates, winged fishplates, bridge fishplates, bonding fishplates, supported fishplates, recessed fishplates, etc. Many of these systems had to be abandoned either on account of the difficulty of fitting them, due to their complicated shape, or on account of their high price.

At one time there was a tendency to lengthen the fishplates in order to effect a greater rigidity of the junction with the rails; thus fishplates with 12 holes were to be found. The answers received show that only fishplates with four or six bolts are now in use.

Creep which is only reported by a few companies is overcome by fixing angle fishplates to the sleepers by means of coachscrews or by angle fishplates, the horizontal wing of which is notched or has shoulders butting against the heads of the coachscrews, or by plates bolted to the web of the rail with a horizontal wing through which the coachscrews project or provided with notches resting the head of the coachscrew.

There is no particularly interesting device in use to eliminate the wear of the bearing surfaces of the plates; the usual practice is to reforge them or to interpose a metal shim between the edge of the fishplate and the rail.

A fish plated joint to remain in good order also requires the bolts to be properly tightened up and that the nuts should not slack back. The majority of the companies who have replied use Grover spring washers for this purpose. Locking and tension plates (fig. 4) are also used. The Ibbotson patent check nut (fig. 4) is also in use.

Welding of rails.

The idea of welding rails has at all times interested the permanent way engineers. But this question was of chief importance for tramway lines which are laid on public roads and electrically equipped, because the question of keeping the joint in good order was in that case more complicated and more costly (re-making the road surface, return current, electrolysis). The experiments made by the tramway companies have resulted in the rapid progress made by the various systems now used in welding rails. At present two systems are universally employed : thermit and electric welding.

As regards light railways, the greater part of the track being laid on its own ground and alongside public roads, the first question to study is the length of rail which can be welded without inconvenience, taking into account expansion. On this length depends the play which must be given at the joint.

As the rail is in no way protected against the variations of temperature, it seems wise in this case not to weld the rails without providing expansion joints. The solution which at the present time seems to combine the greatest continuity of the track in good order under different temperatures, is to weld rails to a length of 60 m. to 90 m. (196 to 295 feet) in one piece. Between two consecutive rails, an ordinary fished joint allows of free expansion. The only objection which could be raised is that of the large size cf the opening at the joints to provide for the expansion between two consecutive welded rails and the maintenance of this opening, nothwithstanding creep.

Let us suppose a welded track in 60-m. (196-foot lengths. The junction points of the rails are fish plated joints. Provision is made at these joints for a possible play of 15 mm. (5/8 inch), which is sufficient to allow for the expansion of the rail.

In central Europe there are differences in temperature of a maximum of 60° C. (— 20° C. to + 40° C.) [108° F. (— 4 to + 76° F.)].

For a difference in temperature of 60° C. the expansion of an entirely free rail 60 m. (196 feet) in length, would be $60 \times 60 \times 0.000012 = 0.043$ m. (1.654 inches).

Experience has shown that in practice the resistance of the coachscrews and of the sleepers reduces the movement due to expansion by half.

A rail of 60 m. in position therefore moves $0.043/2 = 0.021$ m. (0.827 inch).

The joint permits of a movement of 15 mm. (0.590 inch); it results therefrom that the additional stresses introduced into the rail are due to the $21 - 15 = 6$ mm. (0.236 inch) which constitute the difference between the play which would be necessary and that available. These 6 mm. (0.236 inch) are divided into 3 mm. (0.118 inch) non-possible elongation, and 3 mm. (0.118 inch) possible contraction, 3 mm. (0.118 inch) corresponding to variation in temperature of 4° C. (7.2° F.).

$$\frac{0.003}{60 \times 0.000012} = 4°.$$

Consequently a track laid in lengths of 60 m. (196 feet) is not subject between the temperatures of plus 36° C. and minus 16° C. (96.8° and 3.2° F.) to any greater stresses than those to which the fishplated track is subject.

It is sufficient for this that at the moment of laying the opening left at the fishplated joints of the rails be calculated

as a function of the temperature of the rail.

At 36° C. (96.8° F.) no gap is left.

At 30° C. (86.0° F.) there is 2 mm. (0.078 inch).

At 20° C. (66.0° F.) there is 5 mm. (0.197 inch).

At 10° C. (50.0° F.) there is 7 mm. (0.276 inch).

At 0° C. (32.0° F.) there is 10 mm. (0.390 inch).

At — 10° C. (14.0° F.) there is 30 mm. (1.180 inches).

At — 16° C. (3.2° F.) there is 50 mm. (1.970 inches).

Outside these temperatures, *i. e.* plus 36° C. and plus 40° C. (+ 96.8° F. and + 104° F.), minus 16° C. and minus 20° C. (+ 3.2° F. and — 4° F.), the track will therefore be compressed or extended.

The elastic stresses to which the rail will be subjected will be :

$N = E\ \alpha\, t = 20\,000 \times 0.000012 \times 4^\circ = 0.96$ kgr., say 1 kgr. per mm² (0.635 Engl. ton per square inch).

These stresses are evidently negligible.

The *Société des Transports en Commun de la Région Parisienne* states that for its tracks by the side of highroads, on account of the protection given by the ballast of the track coming up very nearly to the running surface of the rail, it has been possible without any drawbacks to weld the rails by the Thermit method in lengths up to 200 m. (656 feet). No provision has been made at the ends of the rails for expansion and no trouble has been experienced.

With the *Société nationale des chemins de fer vicinaux (Belgium)* it is customary to weld rails up to 60 m. (196 feet) in length, and experiments have been made with rails of 72 m. (236 feet) without inconvenience.

On the high roads these two companies weld their rails without providing any expansion joints.

Welding by the alumino-thermic method (thermit).

Welding by the alumino-thermic process is too well known to detain us long.

In this process the rail is completely welded by a single metallurgical operation which is carried out in a crucible and in such time that the reduction is done completely and the deposited metal is freed from all traces of oxide.

At present three processes in this kind of welding are used according to circumstances :

1. *The welding with a clamping apparatus.*

The principle of this welding consists in bringing the heads of the rails to welding heat by means of alumino-thermic reaction, and to weld them by pressure whilst the web and the foot are welded by means of « Calorite » iron which results from the alumino-thermic reaction.

This welding is carried out in the following manner :

The adjacent faces of the heads of the rails are machined by a special milling machine and are brought parallel to one another with the interposition of a welding plate so that no space exists between the heads of the rails. On the contrary a gap must be left between the webs and the feet.

A suitably prepared mould is placed around the rails and allows of the flow of the metal and the corundum produced by the alumino-thermic reaction carried out in an automatic crucible.

Immediately after the flow the two rails are forced against each other by means of a pressure apparatus and the end to end welding of the head of the rail occurs, the web and the foot having been previously welded by means of « Calorite » iron run into the gap between them.

The welded joints must then be properly machined.

2. Welding by the extension press.

The principle of this process is the same as the former, but it is applied when the rails are rigidly held and consequently cannot be pressed one against the other by the pressure apparatus.

The operation differs very little because before any work is done the joint is opened by means of an extension press and the required pressure is provided by the elastic resistance of the rails instead of being obtained by the pressure of the apparatus of the first mentioned system.

3. *Welding by added metal after preheating.*

The principle consists in running into the space between the adjoining faces of two rails « Calorite » iron which melts and welds the rail ends together. Preheating by means of a special apparatus brings the rail ends to a red heat which greatly reduces the number of calories required for the alumino-thermic reaction. The charge can therefore be reduced.

The work is carried out by sawing off one of the two rails so that at the joint there is left a space of 8 to 12 mm. (5/16 to 15/32 inch).

The mould is placed around the joint, the rail ends are preheated and the cast takes place as in the other processes.

Above the top of the rail there remains some « Calorite » iron which is cut off hot, after which the joint is properly machined when cold.

Utilization of these three processes.

The three welding processes above referred to have the same value from the point of view of strength; the joints made by any one of them last as long as the rails.

However, the welding by insertion is not so good as the other two processes, owing to the fact that in the methods the welding has been done with the rails placed end to end whilst in the inserted weld there is to be found, on account of the original gap between two rails a rather large zone of softer metal than that of the rail, and consequently hollow places may form.

It follows from these remarks that the three welding processes should be used in the following cases :

a) Welding with pressure apparatus, to be employed on new or used rails whenever at least one of the rails is free (in cases where there are hollow places the ends must be removed first of all);

b) Welding with an extension press, a process to be used on rails which are already laid in the road when this has properly settled, that is, about one year after laying when the joints are worn and when no hollow places have formed.

All these conditions must be realised in order that this system of welding can give all the desired results;

c) Welding with preheating, a process to be employed on old rails when the two other process are not applicable.

Arc welding.

The first applications of arc welding consisted in spot welding the fishplates to

the heads and flanges of the rails at several points. This was not really a welded joint at all but just a welded fishplated joint.

This system was as a rule only applied to rails already worn, in which case, thanks to its moderate cost, it gave very appreciable savings. Also as a rule, the running surface of the rail which showed hollow places at the ends of the rails was filled in.

However, to be really effective, the welding of rail joints should remain intact as long as the rails themselves in order to arrive at the following results :

1. To prevent hammering by passing vehicles which occasions very high maintenance costs, a premature discarding of the rails and an excessive wear of the rolling stock;

2. To assure a good return circuit for electric lines in order to avoid damage due by electrolysis caused by stray currents.

Judging by the results shown by the welding of fishplated joints, these two conditions cannot be said to have been successfully covered.

This type of welding was soon completed by the addition of a plate welded under the foot of the rail in order to make up for any weakening of the section due to the joint.

For a long time, and indeed at the present moment, this method has been practically the only one used. Hundreds of thousands of joints, principally in tramway lines, have been welded by this method in order to improve already worn track, thereby prolonging the life of rails already condemned, and at but a low cost.

The welding of rails end to end without fishplates has been tried somewhat timidly from time to time, but this weld on a vertical and inaccessible section (web of the rail) would have little strength unless made by highly skilled workmen.

In this direction the *Société nationale des chemins de fer vicinaux* of Belgium, has made tests and the concessionnaire for the sea coast lines (*Company for the Exploitation of the Local Ostend and Belgian Coast Resorts Lines*) has already done much work, having since 1926 welded more than 5 000 end to end joints without fishplates. The procedure is as follows :

The ends of the rails are chamfered off by the electric arc round their periphery with the exception of the lower part of the foot. A steel plate 0.01 m. (3/8 inch) thick and 0.30 m. (11 13/16 inches) long, wedged up previously under the feet of the rails, is then welded to the feet by the electric arc. When this operation is finished, vehicles can pass over the track. Then the periphery of the joint is built up with the arc, after which the joint at the surface is carefully machined smooth.

The quality of the joint obtained depends above all on the skill of the operator and the choice of electrodes.

Messrs *La Soudure électrique autogène*, a company with its headquarters in Brussels, is likewise making tests in the same direction in a scientific and methodical manner. This company points out [1] that if one considers the stresses to which the rail is submitted by bending, one finds that the web only carries a small part. In practice all the stress is taken up by the head and the foot and it is immaterial whether the web is continuous or not. It is, however, obviously necessary to make up for the reduction of the section AB (fig. 5). Consequently

(1) See No. 26, July 1928, of *Arcos*, a review dealing with application of arc welding.

under the foot of the rail a steel plate CD is placed, which is broader by 2 cm. (25/32 inch) than the foot of the rail, and the thickness of which is calculated so as to make up for the loss of section in the web AB.

The *Société nationale des chemins de fer vicinaux (Belgium)* made a test on several joints made by this system on new rails in the following manner :

The plate is placed under the foot of the rail before anything else is done. It is held in place during the welding operation by two heavy wedges EF (fig. 5), which serve at the same time to support the ends of the rails so as to allow of vehicles passing during the operation as well as to set them up so as to reduce the existing hollows when dealing with worn rails. The feet of the rails are then welded to the plate at C and D.

In the first tests, the feet of the rails were in addition welded to each other.

Finally, the top of the rail is bevelled by the arc, welded in the usual manner, and finally built up.

When making impact tests in the laboratory, the rail was found to break outside the weld.

In the bending tests with supports 1 m. (3 ft. 3 3/8 in.) apart the joint broke in the plate beneath the rail foot under a load comparable to that which the rail carries. As to elastic yield the results are equivalent to those of the full rail sections; they are, however, appreciably superior to those of a fishplated joint.

The trial joints made in 1926 in the track of the *Société nationale des chemins de fer vicinaux (Belgium)* have behaved satisfactorily up to the moment.

Recently an improvement has been made in this method. The welding together of the face of the rails has been discontinued and the welding has been limited to that of the foot of the rail to the plate. As, however, it is of value to be able to obtain as great a permanent set as possible before breaking, it is well to leave a part of the plate to bend freely. The welding of the feet will therefore not be done over the full length, but only partially on two sections GH and IK (fig. 6) leaving between them a space HI not welded. This length HI is determined by the permanent set which one wishes to obtain before breakage. As a rule 50 mm. (2 inches) is enough. The laboratory tests have been very conclusive and have given in comparison with the full rail the same tensile strength and elongation and the same elasticity and hardness of the rail surface.

The few joints welded in this manner on the track of the *Société nationale des chemins de fer vicinaux* have not given any trouble so far, and are standing up perfectly.

All these results are very encouraging and if they were conclusive the first cost of a similar welded joint would be very much reduced because the cost of the fishplate forms a third of the cost of arc-welded joints.

Only three companies have given information as to the welding of their rail joints one of which, however, refers only to certain particular cases such as on structures and in tunnels. The two others : the *Société des Transports en Commun de la Région Parisienne* and the *Société nationale des chemins de fer vicinaux (Belgium)* employ welding on a large scale, are very satisfied with it and are developing it more and more.

Sleepers.

The use of sleepers is general.

As to the kind of sleepers, wood, iron [illegible]

or concrete, naturally in making a choice, local conditions and economic considerations must be taken into account.

The three types of sleepers appear to give track of equal quality. The weak point of each is in the rail fastening.

Of all the companies who have replied, twenty-four use wood sleepers exclusively, five both wood and metal sleepers, one uses wood, metal and reinforced concrete, and three wood and reinforced concrete.

The spacing of the sleepers in the open varies between 0.75 m. (2 ft. 5 1/2 in.) and 0.80 m. (2 ft. 7 1/2 in). This spacing is reduced at the joint to from 0.45 m. (1 ft. 5 11/16 in.) to 0.50 m. (1 ft. 7 11/16 in.).

Wood sleepers.

Until 1914 the majority of European railway and tramway systems used the wood sleeper which had proved itself and had given satisfaction from the technical point of view and which did not seem to be able to be competed with economically by any other material such as iron or concrete.

Local conditions usually decide the choice of wood used for wood sleepers, and economic conditions govern the treatment of the sleeper by creosoting.

The desire to have a track which does not require constant attention and frequent inspection by the maintenance personal to keep it in order, is general. Furthermore, owing to the mechanical work which the sleeper has to support on curves on to which in spite of all care the vehicles run with successive impacts, there is the tendency to employ hard wood sleepers. By hard wood, in European countries, oak and beech are usually meant. Among soft woods pine, spruce and similar woods are included.

Foreign hard woods are little used but all the same it would be interesting in view of the scarcity of wood, to make experiments with colonial hard woods. From this point of view, it is useful to enumerate the essential requirements which a wood suitable for sleepers must satisfy [1]:

1. To resist decay through humidity, fungus, etc.;

2. To be hard but at the same time not prevent the penetration of antiseptics which are to assure its preservation. It is on this resistance against crushing that the quality of a sleeper will depend in order to bear the train loads without breaking or splitting;

3. To lend itself to boring and to driving the coachscrews without splitting or crushing so as to ensure the rails being well held;

4. To be sufficiently elastic as to give a smooth road;

5. To be homogeneous, *i. e.* that the same species of timber does not consist of too many different varieties so that the track may be uniform throughout in its entire length.

To sum up, the real question in the choice between hard and soft woods is that of economy. The problem depends on the price of the wood, on that of the impregnation, on its durability, and on the price of fixing the fastenings, or of re-adzing. It is after calculating all these facts of the problem that Administrations will decide finally which sleeper is to be used.

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(1) Extract from the article « L'Utilisation des bois coloniaux pour les traverses de chemins de fer » (The use of colonial timber for railway sleepers) in the review *Les chemins de fer et les tramways*, issue of January 1928. See also *Bulletin of the Railway Congress*, June 1928 number, p. 479.

Of the answers received, thirteen companies use exclusively oak, six spruce only, six use both oak and beech, three oak and spruce.

Many companies impregnate their wooden sleepers, whatever may be the kind of timber, in order to increase their life. Seven companies report, however, that in this respect they do nothing. Four do not impregnate their oak sleepers.

It is admitted that up to now the best results as regards preservation of the wood have been obtained by injection under pressure (after being subject to vacuum) in autoclaves with heated creosote oil obtained from coal tar. Nineteen companies use creosote, one company employs sulphate of copper as an antiseptic, and two companies use the Rueping system of injection of hot tar oil.

One company is content to dip the sleepers in a bath of cold carbonyl.

On the *Société nationale des chemins de fer vicinaux (Belgium)* an immersion for four to six hours in a bath of cold creosote has been tried for some years. This creosote is an oil extracted from coal tar and rich in phenol. Its great fluidity allows of a deep absorption by the wooden tissues by simple dipping.

If these experiments were to give the anticipated results the system would have entailed great economies in working expenses and in transportation compared with the former system of creosoting under pressure; furthermore it is extremely flexible because the operation could be carried out direct at the timber yard with simple and easily movable apparatus, as and when the work requires it.

The *Société des Transports en Commun de la Région Parisienne* uses for its tramways only sleepers made of the heart of oak and estimates that in this case any impregnation or dipping is useless and, besides, deceptive.

It is difficult to give an exact estimate as regards the life of a wood sleeper, because it depends on a great many factors, but it seems from our enquiry that for a line carrying moderate traffic impregnation with an antiseptic doubles the life of a sleeper.

Metal sleepers.

The question whether the advantage is in favour of the wooden or the metal sleepers has been very much discussed. As with wooden sleepers, the problem seems to reduce itself to one of economy, and as the engineer, Mr. Burton said in 1926 in his report to the International Congress of Tramways, Light Railways and Motor Transportation, at its session in Barcelona : « The importance of the life of the sleeper is almost decisive because for track of about equal quality, it can make it an economy to use a very expensive sleeper, and an extravagance a sleeper of a ridiculously low purchase price. »

The life of the sleeper, however, depends much on circumstances such as the mechanical wear which results from the effectiveness of the rail fastenings, the maintaining of the gauge and the influence of the soil and sub-soil. Finally, the nature of the ballast used also enters into the calculation.

The old controversy between the partisans of wood and those of metal has not yet been decided.

However, from the point of view of durability, the metal sleeper seems to be better than the wooden sleeper.

The metal sleeper however cannot be used in all cases. In this respect it is well to recollect what Mr. Vincent said in

his note which appeared in the *Bulletin of the Railway Congress*, No. 10, of December 1928, p. 1056 :

Sleepers, whatever they may be made of, have to do two things :

1. Distribute over the ballast the pressures transmitted from the wheels of the vehicles;

2. Tie together the rails.

The causes of fatigue or deterioration they suffer are :

a) Either : mechanical action (pressure of the rail which causes the foot to be driven in, or the sleeper to bend, movements of the rail which give rise to wear by grinding away or tear out the coach screws, vibrations which result in certain materials breaking up and the fastenings becoming loose) ;

b) or : atmospheric action (dryness, wet, impurities in the air) ;

c) or : various actions as for example the attack of insects in tropical countries.

These different points can be kept in mind with advantage as some sleepers which stand up well against certain of these agencies, do not, on the contrary, against the others so that it might show good judgment to use one kind of sleeper under conditions which would prevent the employment of sleepers of a different kind.

The metal sleeper, by its very nature, stands up to certain of these destructive forces. It should also, in addition, thanks to its method of manufacture, show sufficient strength not to get out of shape, nor to break under the loads it has to carry and should ensure that the forces are transmitted to the ballast; it should have a shape that will oppose longitudinal and lateral movements and still be easy to tamp; it should be fitted with a simple, but at the same time strong rail fastening. Finally its weight should be sufficient to make the track stable which latter condition is readily obtained with the metal sleeper.

Before the world war, the problem of the metal sleeper, so to say, did not arise, but since the war economic conditions have been upset in all European countries. The destruction of forests through acts of war and the intense exploitation of other forests for military purposes and for supply after the war, have caused a considerable rise in the price of wooden sleepers and the question of replacing these by metal or ferro-concrete ones has had to be faced.

This problem has therefore been closely studied and experiments in laying down these two types of sleepers have been undertaken more seriously and on a larger scale.

In France especially the *Union des voies ferrées et des transports automobiles* has produced a type of metal sleeper in two patterns, each of which can be employed either for normal gauge or for metre gauge, and which is at present very largely used.

The features of these patterns are the following :

Track of 1 m. (3 ft. 3 3/8 in.) gauge : *a*) light section (fig. 7, No 1). corresponding to a weight of about 32 kgr. (70.5 lb.) per sleeper of 1.70 m. (5 ft. 7 in.) length; *b*) heavier section (fig. 7, No. 2) corresponding to a weight of about 38 kgr. (83. 8 lb.) per sleeper of 1.80 m. (5 ft. 11 in.) length.

Track of 1.435 m. (4 ft. 8 1/2 in.) gauge : *a*) light section weighing about 44 kgr. (97 lb.) for sleepers 2.20 m. (7 ft. 2 5/8 in.) in length; *b*) heavier section, weighing about 49 kgr. (109 lb.) for sleepers of 2.20 m. (7 ft. 2 5/8 in.) length.

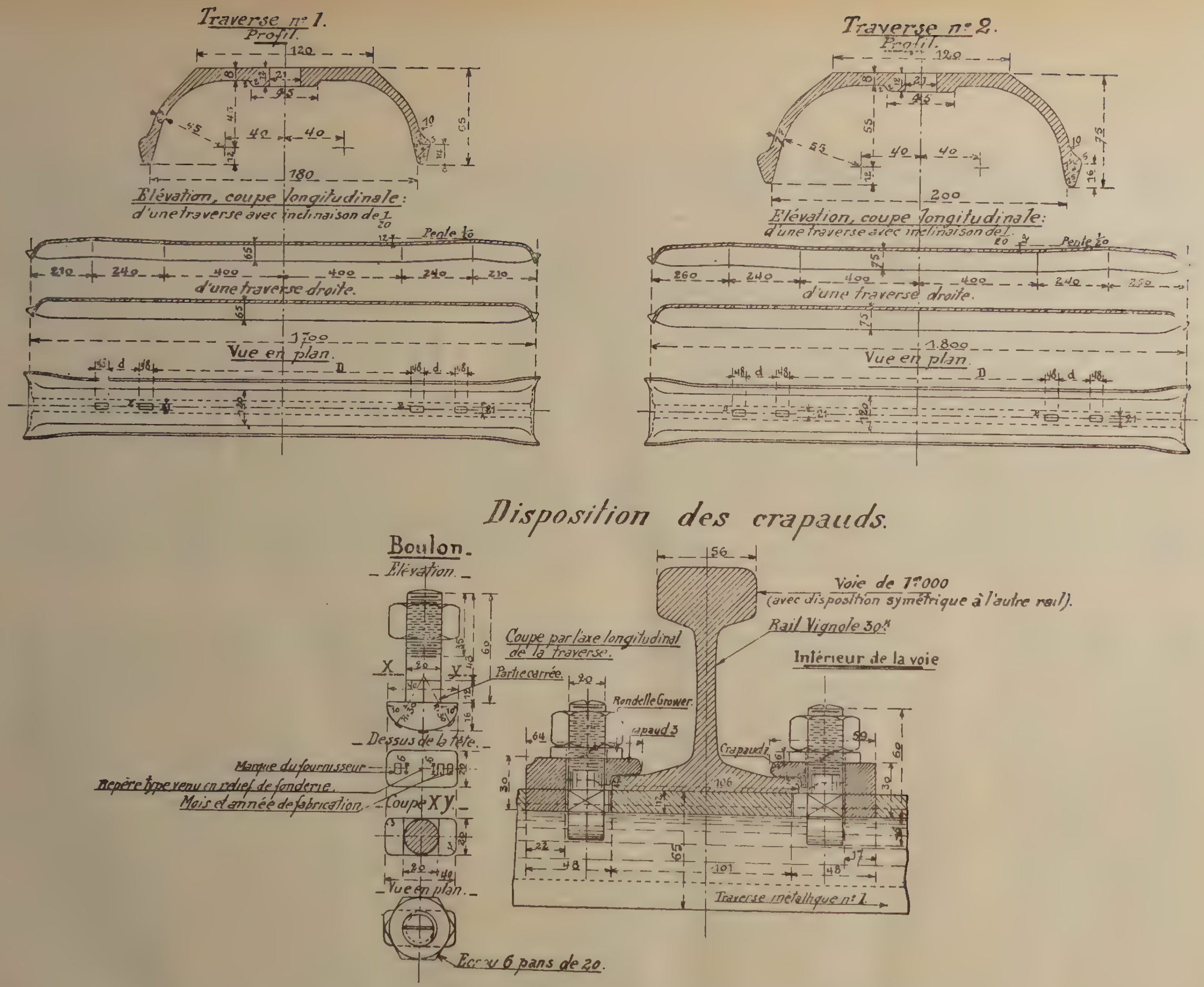


Fig. 7. — Standard profiles of the « Union des voies ferrées et des transports automobiles ».

Explanation of French terms: Boulon = Bolt. — Coupe par l'axe longitudinal de la traverse = Section on longitudinal axis of the sleeper. — Crapaud = Clip. — Dessus de la tête = Top view of the head. — Disposition des crapauds = Layout of the holding down clips. — Elevation, coupe longitudinale d'une traverse avec inclinaison de 1/20 = Elevation — longitudinal section of a sleeper with an inclination of 1:20. — D'une traverse droite = Of a level sleeper. — Intérieur de la voie = Four-foot. — Profil = Profile. — Rail Vignole de 30 kgr. = 30 kgr. 60.48 lb. per yard) Vignoles rail. — Rondelle Grower = Grower washer. — Traverse métallique n° 1 = No. 1 metal sleeper. — Traverse n° 1 = Sleeper No. 1. — Voie de 1 m. avec

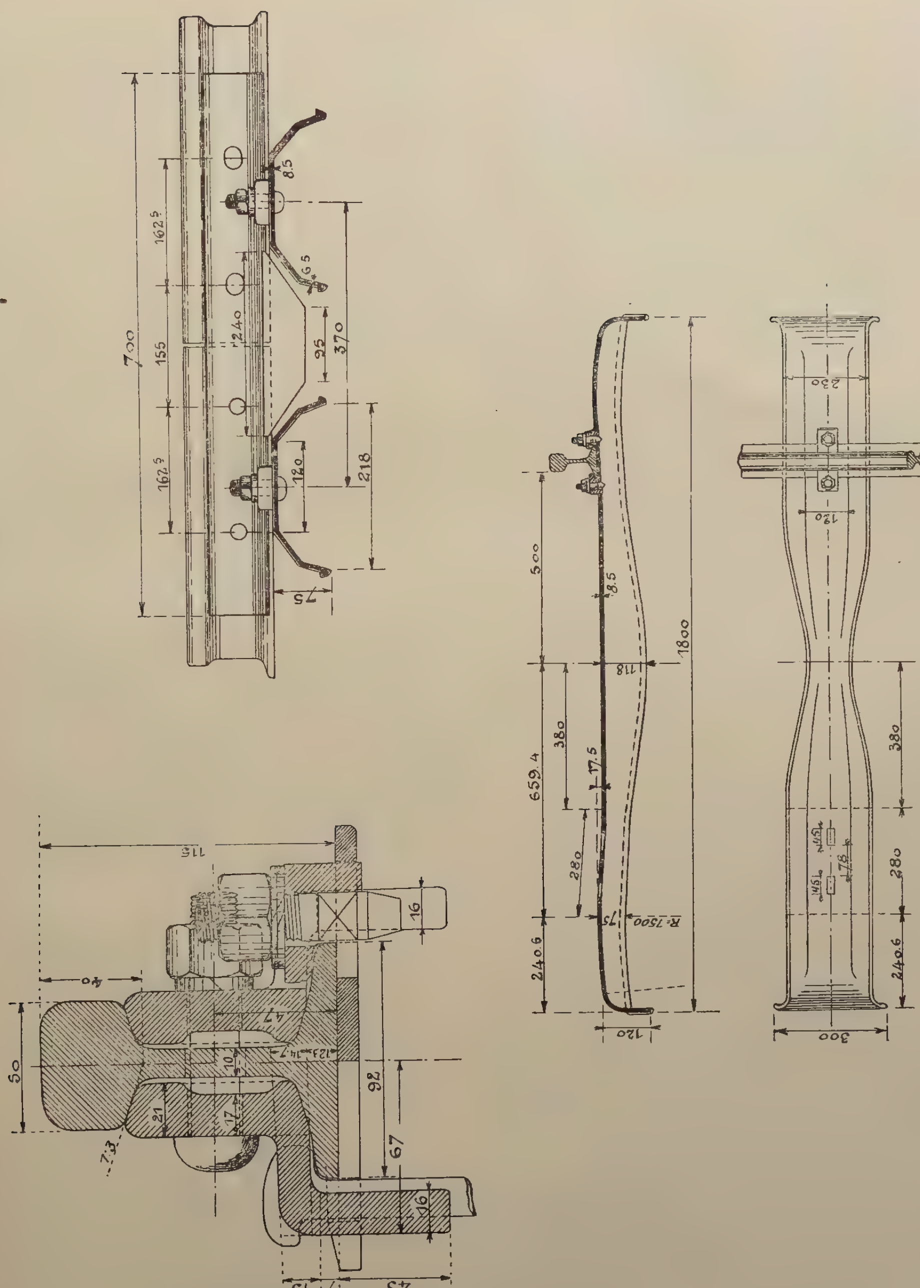

700
155
1625
1625
240
95
370
218
120
8.5
6.5
75
1800
500
659.4
240.6
380
280
17.5
8.5
118
R=7500
75
120
300
230
120
380
280
240.6
116
40
47
50
92
67
16
21
17
10
7.3
16
15
7
43

Fig. 8.

These various sleepers can be made with the rail bearing surface either horizontal or inclined 1 in 20.

The rail is fastened by clips and bolts.

Three patterns of clips are available which differ only in the dimensions of the heel, thereby permitting five combinations by which the gauge of the track can be varied by 10 mm. (3/8 inch).

The sleepers are closed at the ends so that the ballast which is well tamped inside may form a compact core which increases the stability and counteracts lateral displacement.

The French Companies who have answered the sheet of questions and who employ metal sleepers, make use of this standard type, or of one very much like it.

The *Rhætian Railways* (Switzerland) use metal sleepers according to figure 8. They use four types of clips, permitting variations in the gauge by 24 mm. (15/16 inches).

Characteristics of the sleeper for metre gauge track : weight about 37 kgr. (81.6 lb.) for 1.80 m. (5 ft. 11 in.) length.

The various companies which use metal sleepers estimate that their life is certainly longer than that of wooden sleepers. In order to obtain efficient tamping the ballast must be of better quality. The metal sleeper results in the gauge of the track being very regular. The fitting up of the sleeper is done quickly, the stability of the line is very good, its elasticity is, however, less than with the wooden sleeper.

From the economic point of view, in order to compare the metal and the wooden sleepers, it is necessary to regard : the purchase price, the cost of laying, the upkeep cost, the cost of renewals and the recovery value of the sleepers when unfit for further service. These various points depend often on local and traffic circumstances and a definite answer to the question which of the two sleepers is the more economical one, is difficult to give.

Concrete sleepers.

The fashion for ferro-concrete could not fail to induce the railway companies to make experiments with sleepers of this material, hoping thereby to obtain very long life, through its strength and its resistance to atmospheric influences.

The first experiments of any importance were made in Italy. These did not meet with the expected success because the prismatic shape of the wooden sleepers had been adhered to too closely, and furthermore the fastenings copied from those used with wooden sleepers consisted of a threaded coachscrew in a wooden plug set in the concrete.

Closer investigation has proved that if the concrete sleeper is to fulfil the same purpose and resist the same causes of strain and deterioration as the wooden or metal sleepers, the way in which the ferro-concrete sleeper behaves under load must also enter into the calculation. M. R. Desprets in his « Note on some recent types of reinforced concrete sleepers » which appeared in the *Bulletin of the Railway Congress* of July 1922, wrote:

« We draw attention to the fact that « there is a fundamental technical difference between wood and ferro-concrete « sleepers of a prismatic form.

« The length of the former is determined by a condition which might be called « of equal deformation for the sleeper « whilst the length of the second is governed by the condition which might be « called of equal resistance, that is realising the equality of the bending moments under the rails and in the middle

« of the sleeper. » Mr. Desprets thus gives an explanation of the fracture of the first ferro-concrete sleepers, the length of which, approximately 2.60 m. (8 ft. 6 3/8 in.) for normal gauge, was excessive.

As the engineer Mr. Vincent writes in his article « Comparison between wood, metal and ferro-concrete sleepers » [1] which appeared in the review « L'Industrie des voies ferrées et des transports automobiles », the principal qualities which ferro-concrete sleepers must show are the following :

1. Sufficient strength to resist without breaking and without cracking the considerable bending moments which may be set up at the centre or at the end of the rail.

2. Absence of brittleness so as not to suffer damage when being handled or when being tamped.

3. Hardness to resist disintegration at the rail seats.

4. Rigidity to properly distribute the stresses over the ballast.

5. Simple and reliable fastenings which do not become loose under the influence of vibration and which allow, if possible, existing parts to be used.

6. The bottom surface must be sufficiently rough to avoid movement through slipping on the ballast.

7. Easy manufacture in shops as near as possible to the site where used.

8. Low cost price.

At present the ferro-concrete sleepers belong in principle to two types :

1. The first type is of a shape which imitates that of the wood sleeper adopting, however, the form of a prism of variable section.

2. The second type consist of two supports with a wide base which are connected either by a small metal bar or by a ferro-concrete part of reduced width.

The sleeper designed and built by the Camargue Railway (France) for metre gauge belongs to the first mentioned type. It has been in use for more than seventeen years and in its final design gives complete satisfaction.

Figure 9 shows its form and characteristics. The reinforcement is composed of four bars of 12 mm. (15/32 inch) joined by ties. The rail seat is inclined 1 : 20. The fastening if the rail consists of a coachscrew which screws direct into the concrete in a hole prepared when moulding the sleeper.

The method of fastening by a coachscrew requires one indispensable precaution. The threaded holes must be exactly alike and the coachscrew used be correct to gauge, otherwise there is a risk of cracks and even of breaking away of the concrete at the moment of tightening the fastenings. Through such accidents the sleeper becomes scrap.

On the other hand, the replacement of a damaged coachscrew may offer similar difficulty.

Another question presents itself : that of the resistance of the concrete threads of the holes for the coachscrews under the stress to which they are subjected. Practice only can assure us. Will the threads last as long as the sleeper ?

Price : French fr. 15.35 for the bare sleeper at works.

The Gaudin sleeper which has been experimentally laid down by the *Nantes Tramway Co. since* 1924 can also be regarded as belonging to the first type, but

(1) Report presented the 4th General Technical Meeting (Marseilles, 6, 7 and 8 November 1927).

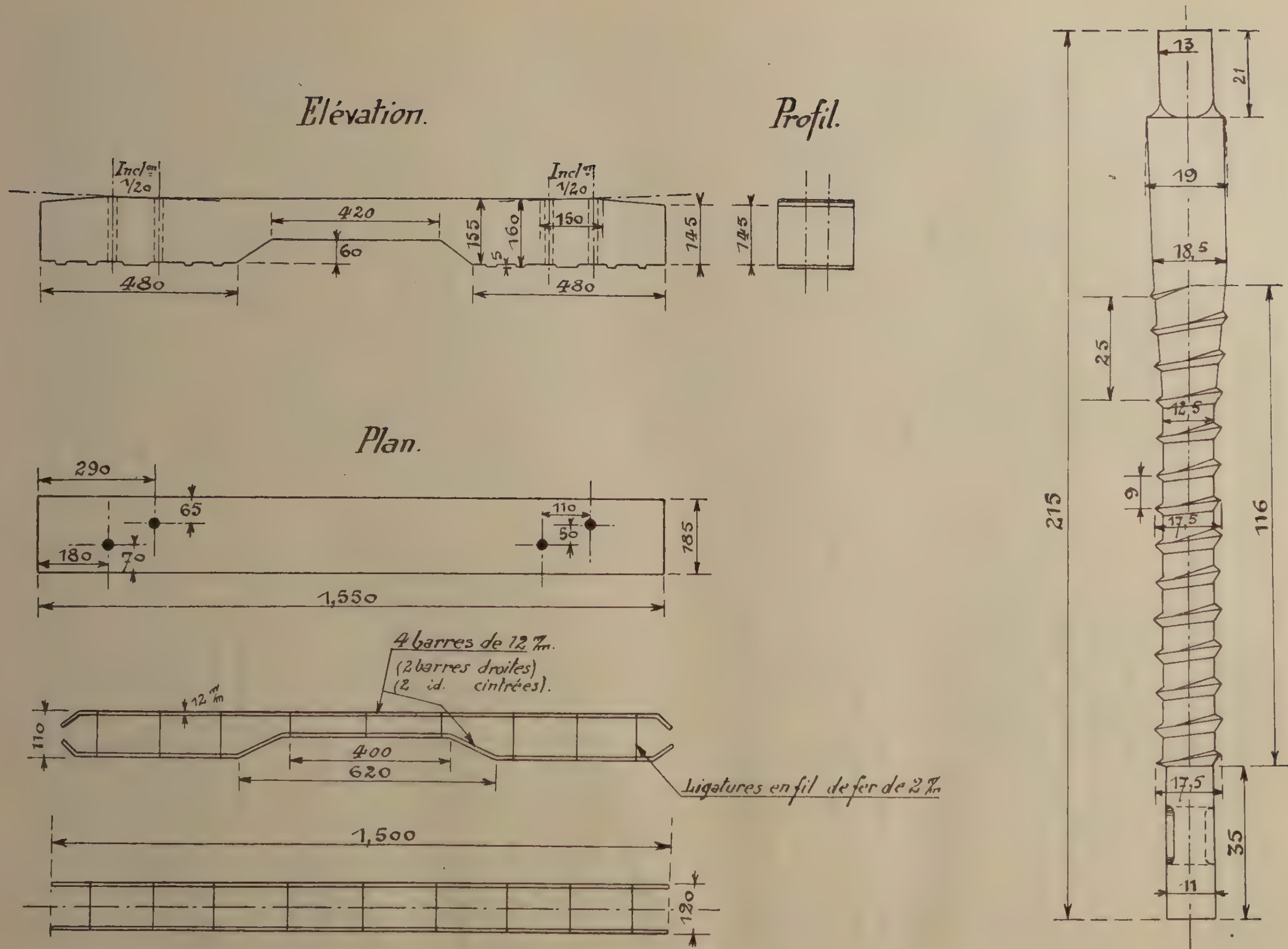


Fig. 9. — Ferro-concrete sleeper, Camargue type, and coachscrew.

Explanation of French terms : Elévation = Elevation. — Incl^{on} 1/20 = Inclination 1 : 20. — Ligatures en fil de fer de 2 m/m. = 5/64 - inch wire bindings. —

its prismatic section is hollowed out at the centre and at the ends. Figure 10 shows the arrangement. It has a length of 2.10 m.(6 ft. 10 5/8 in.) for the 1.435 m. (4 ft. 8 1/2 in.) gauge and weighs 86 kgr. (189.6 lb.) The rail fastening is by clips and nibbed bolts; it has stood the test well.

To the second class of sleepers belong the Vagneux sleepers and those of the *Société des Transports en Commun de la Région Parisienne (S. T. C. R. P.)* The Vagneux sleeper comprises two types : the sleeper with foot [fig. 10 (A)] and the composite sleeper [fig. 10 (B)].

At present it is the composite sleeper which is most in use. The central part is a metal beam of I section fixed by simple adhesion in the two ferro-concrete heads. In order to avoid the danger of the bar rusting, it is protected by a good coat of black metal varnish.

The fastening of the rail can be done either by a coachscrew which is screwed into an opening in the concrete moulded by means of a carefully gauged threaded rod. When moulding this rod is provided with a metal helicoidal fitting (Thiollier spiral) which remains embodied in the concrete so as to form part of the opening, the cylindrical wall of which it touches (fig. 11), or by means of a coachscrew bolt with clips (fig. 12).

The sleeper for the 1.435 m. (4 ft. 8 1/2 in.) gauge track weighs 150 to 175 kgr. (331 to 386 lb.) according to the models (150 kgr. for the track with chairs and 175 kgr. for the track of Vignoles rails).

The rail is not carried directly on the concrete. The rail seat is protected by a sole plate made of wood for which a space 4 to 10 mm. (5/32 to 3/8 inch) deep is recessed in the concrete.

The mixture of the concrete varies, according to the case, between 300 and 400 kgr. (660 to 880 lb.) of artificial cement for a mixture of 400 l. (14.12 cubic feet) of sand from 0-5 mm. (0 to 3/16 inch) and 800 l. (28.24 cubic feet) of coarse gravel of 5-25 or 30 mm. (3/16 to 1 or 1 3/16 inches) or for 1 200 l. (42.36 cubic feet) of a mixture which will enable one to obtain a more compact concrete.

The sleepers of the S. T. C. R. P. type are of two patterns :

a) Figures 13 and 14 where the rail is fastened by means of coachscrews;

b) Figures 15 and 16 where the rail is fastened by means of clips and bolts.

Weight : 75-80 kgr. (165.3 to 176.4 lb.) per sleeper for track of 1.435 m. (4 ft. 8 1/2 in.) gauge.

Composition of the concrete : Portland cement: 500 kgr. (1 100 lb.); coarse gravel 6-8 mm. (1/4 to 5/16 inch), 0.500 m^3 (17.6 cubic feet); and fine sand 0.500 m^3 (17.6 cubic feet).

Price : French fr. 50 to 60, including fastenings.

With one and the other of these two kinds a sole plate of teak wood is placed between the foot of the rail and the sleepers.

When the sleeper is not machined at the rail seat, the simple flat board of a width as near as possible to the transverse distance between the coachscrew holes is insufficient. In fact, under these conditions the coachscrew is not externally shouldered so that when the head touches the foot of the rail the slightest tightening makes it bend outwards. A test made with a tempered steel coachscrew did not give much better results. The ordinary boards have been replaced therefore by sole plates having the same section as the machined part of the wood sleeper. With

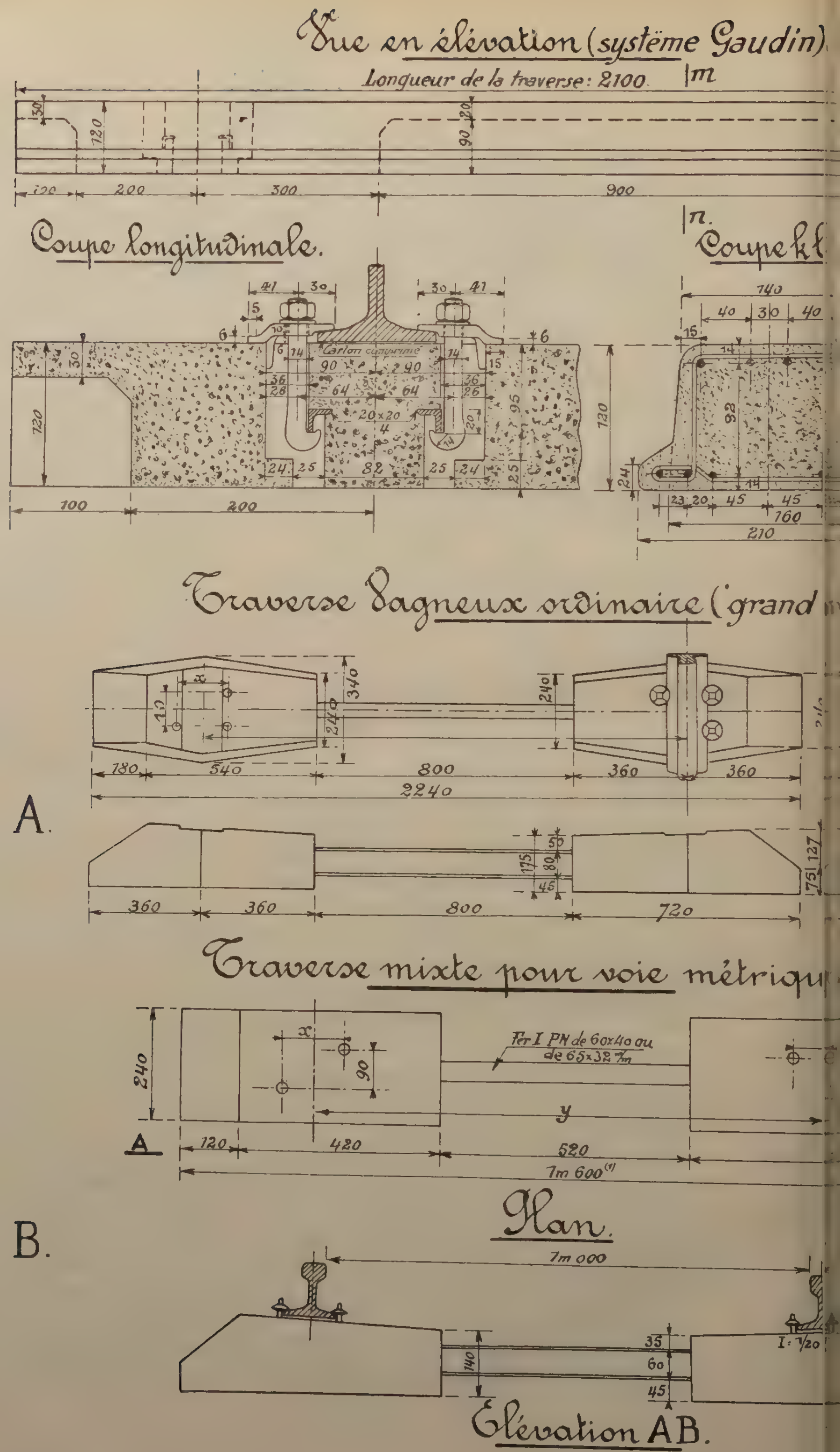
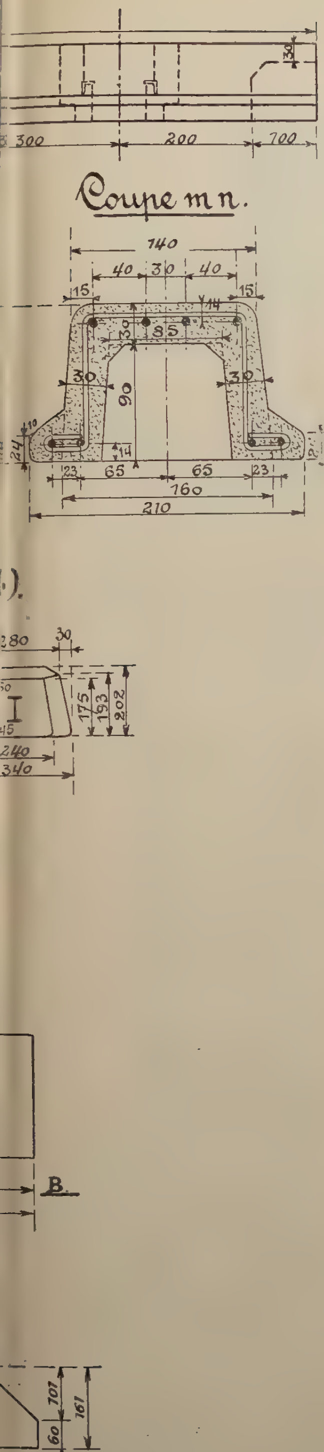

Vue en élévation (système Gaudin)
Longueur de la traverse: 2100 m/m
Coupe longitudinale.
Carton comprimé
Coupe
Traverse Vagneux ordinaire (grand
A.
Traverse mixte pour voie métriq
Fer I PN de 60x40 ou de 65x32 m/m
7m 600
B.
Plan.
7m 000
I: 1/20
Élévation AB.

Fig. 10.



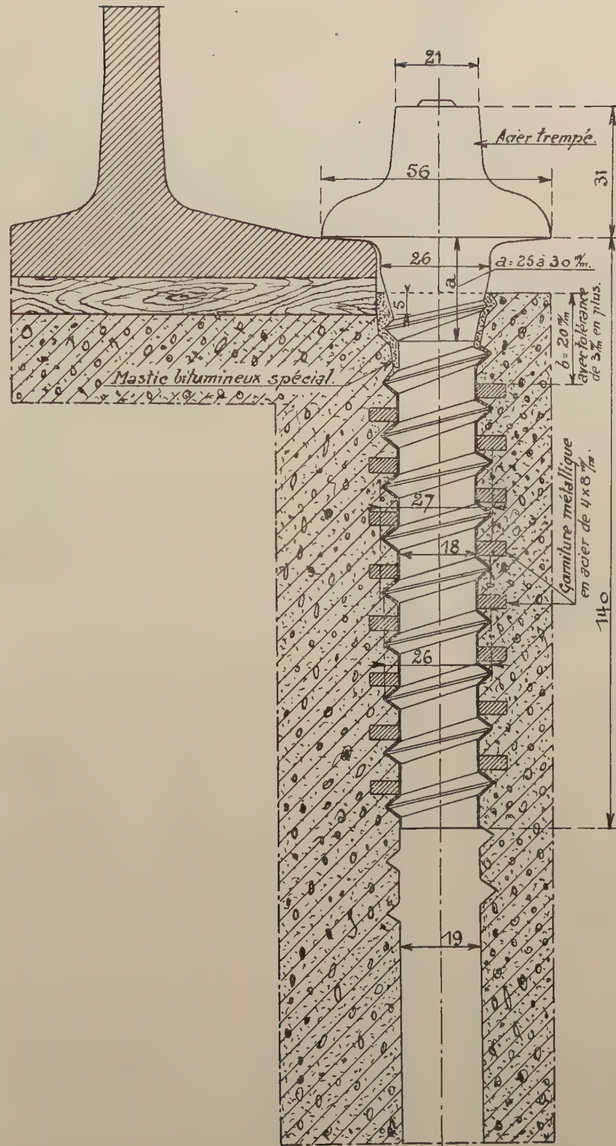


Fig. 11. — Detail of the fastening by special coachscrew.

Explanation of French terms in figures 10 and 11 :

Acier trempé = Tempered steel. — Avec tolérance de 3 m/m. en plus = With tolerance of + 1/8 inch. — Coupe = Cross section. — Coupe longitudinale = Longitudinal section. — Garniture métallique en acier = Metal lining in steel. — Longueur de la traverse = Length of sleeper. — Mastic bitumineux spécial = Special bituminous cement. = Traverse mixte pour voie métrique = Composite sleeper for metre gauge track. — Traverse Vagneux ordinaire (grand modèle) = Vagneux ordinary sleeper (large model). — Vue en élévation (système Gaudin) = Elevation, Gaudin system.

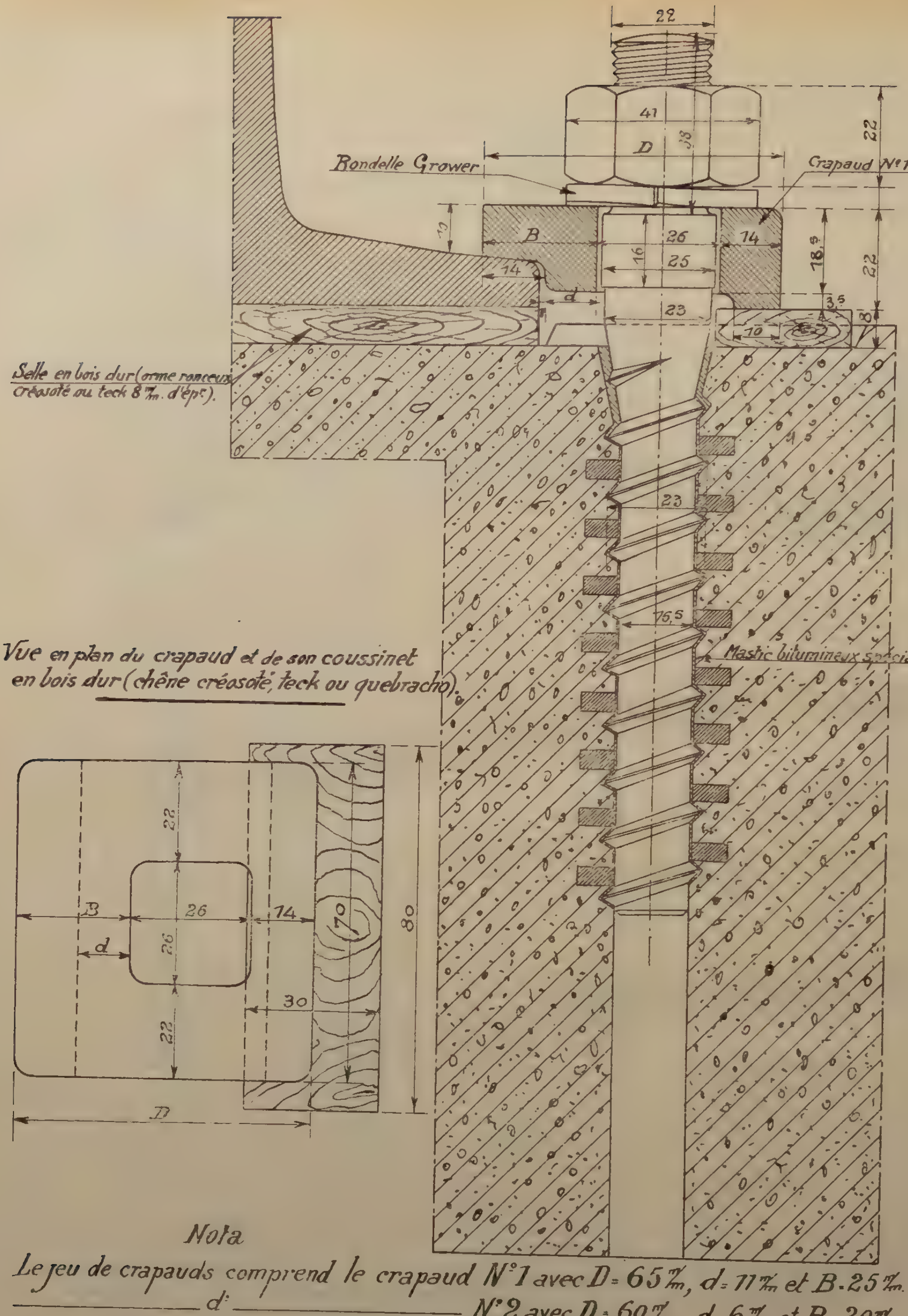


Fig. 12. — Ordinary fastening using a coach screw bolt.

Explanation of French terms : Crapaud N° 1 = Clip No. 1. — *Nota.* Le jeu de crapaud comprend etc... = *Nota* The set of clips includes the No. 1 clip with D = 65 mm. (2 9/16 inches), d = 11 mm. (7/16 inch) and B = 25 mm. (63/64 inch). The set of clips includes the No. 2 clip with D = 60 mm. (2 3/8 inches), d = 6 mm. (15/64 inch) and B = 20 mm. (25/32 inch). — Rondelle Grower = Grower washer. — Selle en bois dur (orme ronceux créosoté ou teck 8 m/m d'épaisseur) = Hard wood (creosoted elm or teak packing 5/16 inch thick. — Vue en plan du crapaud etc... = View in plan of the clip and its bearing of hard wood (creosoted oak, teak, or quebracho).

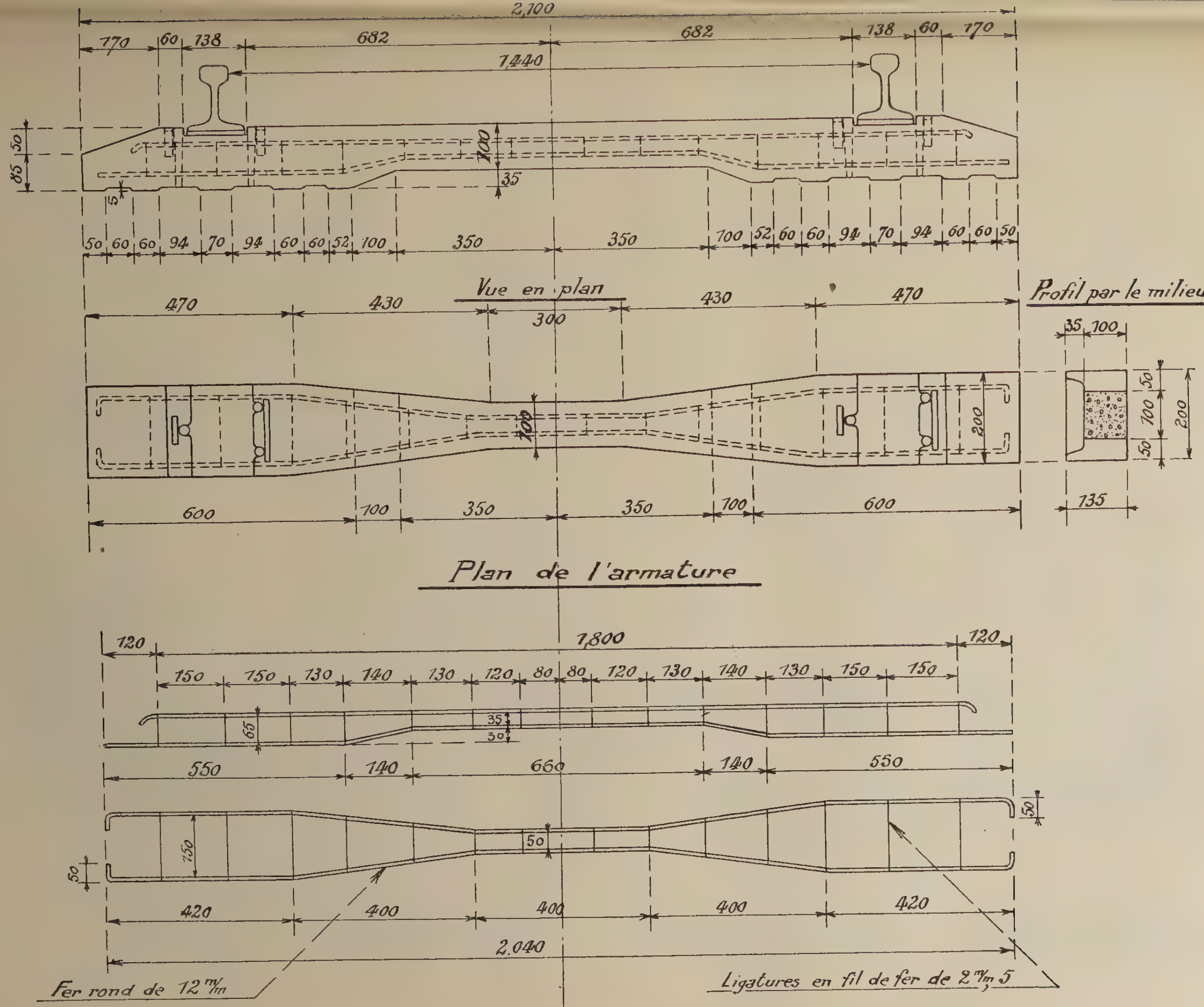


Fig. 13. — Ferro-concrete sleeper, T. R. C. P. type, with coachscrew rail fastening (general view).

Explanation of French terms : Fer rond de 12 m/m = Round steel 12 m/m. (15/32 inch). – Ligatures en fil de fer de 2 m/m 5 = Binding wires of steel 2.5 m/m. (0.098 inch). — Plan de l'armature = Plan of the reinforcement. — Profil par le milieu. = Profile at the middle. – Vue en plan. = View in plan.

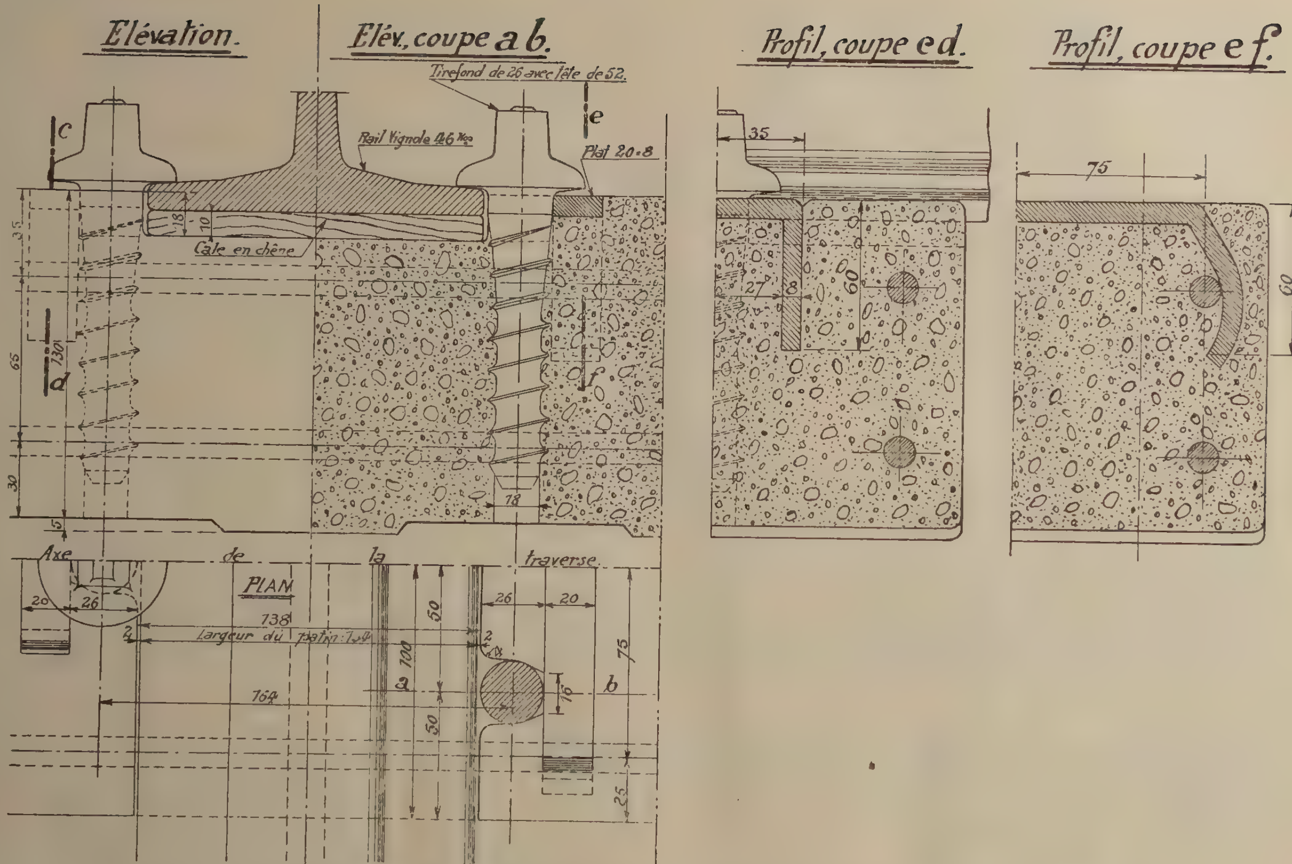


Fig. 14. — Ferro-concrete sleeper, T. R. C. P. type with coach screw fastening. Detail of fastening.

Explanation of French terms : Axe de la traverse = Centre line of the sleeper. Cale en chêne = Oak packing piece. — Elev. coupe *ab*. Rail Vignole 46 kgr. = Elevation, section *ab*, Vignoles rail 46 kgr. (92.7 lb. per yard). — Largeur du patin : 134 = Width of the foot ; 5 1/4 inches. — Plat 20 × 8 = Flat 25/32 × 5/16 inch. — Profil, coupe = Profile section. — Tirefond de 26 avec tête de 52 = Coach screw 1 1/32-inch with 2 1/16-inch head.

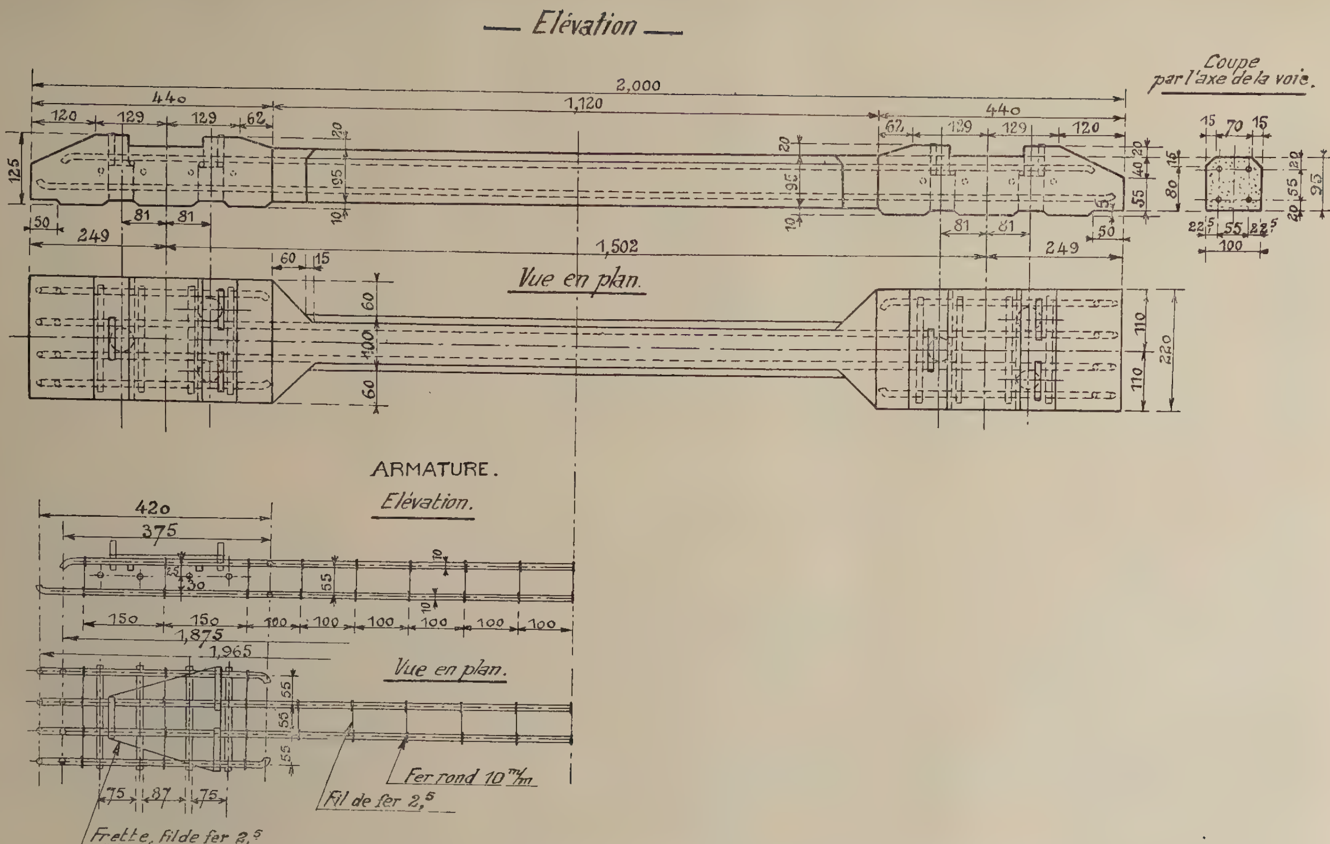


Fig. 15. — Ferro-concrete sleeper, T. C. R. P. type with bolt and clip fastening.

Explanation of French terms : Armature = Reinforcement. — Coupe par l'axe de la voie = Section on the centre line of the track. Fer rond 10 m/m. = Steel bar 10 mm. (3/8 inch). — Frette fil de fer 2.5 = Clip, steel wire 2.5 mm. (0.098 inch).

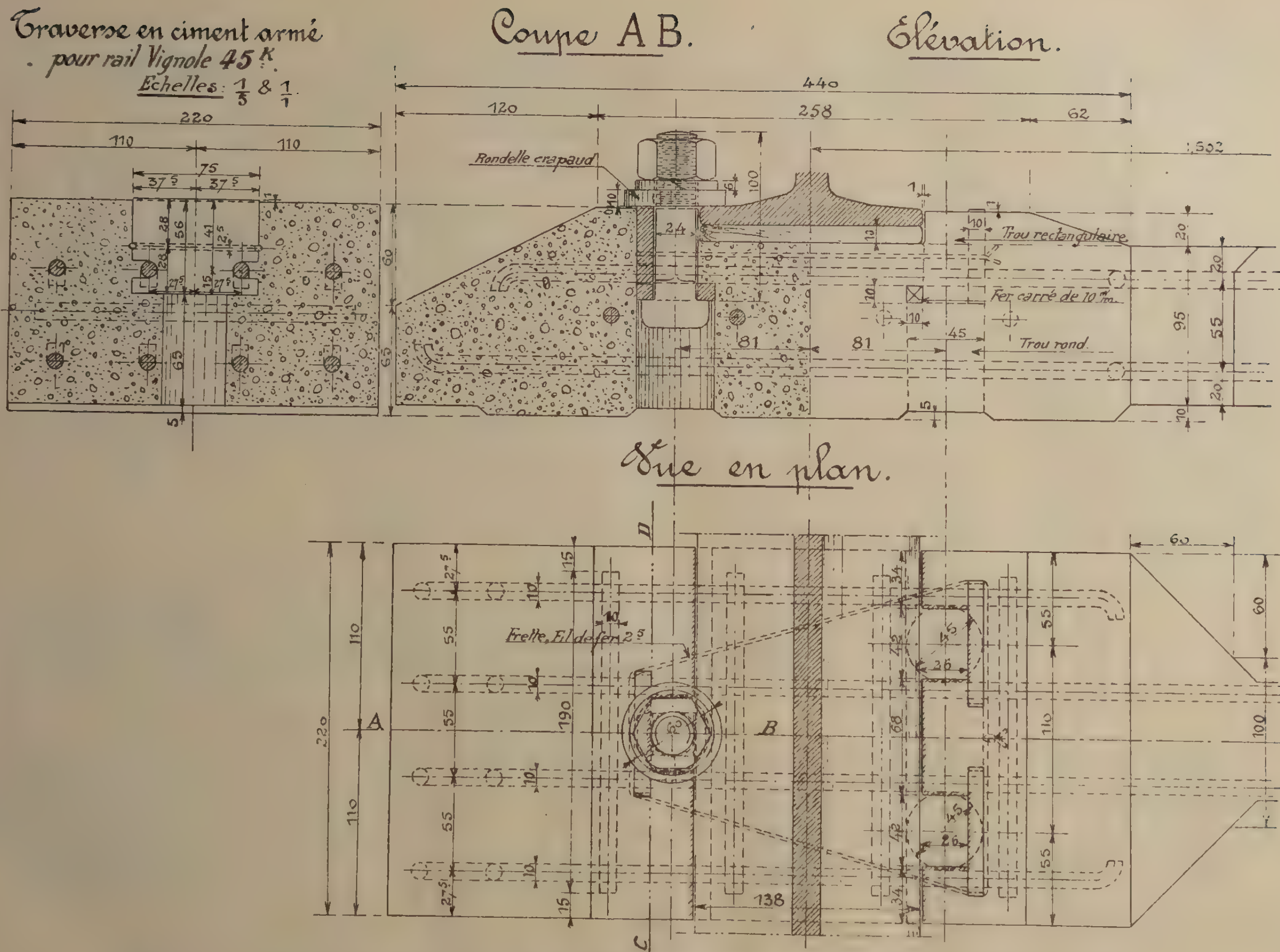


Fig. 16. — Ferro-concrete sleeper, T. C. R. P. type, with bolt and clip fastening. - Detail of fastening.

Explanation of French terms : Fer carré de 10 mm. = Square steel of 3/8 inch. — Frette fil de fer 2.5 = Clip of 0.098-inch. steel wire. — Rondelle crapaud = Clip washer. — Traverse en ciment armé pour rail Vignole 46 kgr. = Ferro-concrete sleeper for Vignoles rail of 92.7 lb. per yard. — Trou rectangulaire = Rectangular hole. — Trou rond = Round hole.

this arrangement the coachscrews do not bend any more and a good contact between the rail and the sleeper has been obtained.

The dressed sleepers are more economical than those not machined, because they do not cost more than the latter and they make it unnecessary to use relatively expensive profiled sole plates (1).

Although the experiment has been of short duration, the S. T. C. R. P. estimates that the bolt and clips fastening is better than that with coachscrews. These sleepers, it says, must show important economic benefits in track laid beside high roads where the sleepers are soaked by house water which causes the wood sleepers to rot and the metal ones to rust, but which has no effect on those of concrete. Therefore, although a little dearer, the concrete sleeper should give much longer service. At the moment of laying, some sleepers (a small proportion) have become fissured, either in the central portion or in line with the fastening by a coachscrew. The company remarks that it has been found that this kind of accident originated from the fact that owing to an error in the manufacture the reinforcement iron was too far distant from the top of the sleeper. The middle portion is in fact frequently, and particularly during laying, subjected to bending stresses which strain its upper fibres, either because the heads are unequally tamped, or because the centre of the sleeper bears on the ballast. If the reinforcing bars are placed too low, the concrete will inevitably split away.

The *Compagnie des Tramways Départementaux des Deux-Sèvres* uses a ferro-concrete sleeper very like the Vagneux type with foot (fig. 17). Its weight is between 55 and 65 kgr. (121 and 143 lb.) of which 4.5 kgr. (10 lb.) is represented by iron. The composition of the concrete is : cement 6.100 kgr. (13.44 lb.), gravel 19 dm^3 (0.67 cubic foot), sand 9 dm^3 (0.32 cubic foot). The price is very favourable: French fr. 10 to 12. The rails are fastened with bolts and nuts.

To sum up, the ferro-concrete sleeper is relatively easy to handle. Its weight does not exceed 80 kgr. (176 lb.). The laying does not present any special difficulties although it takes a little longer than the wood sleeper. Tightening is easy, the stability of the track is good.

Almost all kinds of ballast are suitable. However, a ballast of very hard broken stone in large pieces, and round gravel is not to be recommended.

As regards life the experiments in hand allow one to hope that sleepers in ferro-concrete when designed and well constructed will have a considerably longer life than wood ones. This duration seems to be a matter of the strain sustained and consequently of the number of trains carried rather than age.

Points and crossings.

The fittings can be divided into two groups, the turnouts and the crossings.

When a track divides into two or three branches the junction is effected by means of a turnout. It consists of two parts :

1. The switch with movable points establishing continuity, according to the position of same, with the principal line or with the branch line;

2. The crossing allowing the wheels to pass over the line left behind.

(1) Note by Mr. Gagné, chief engineer of the *Société des Transports en Commun de la Région Parisienne* on his experiments with ferro-concrete sleepers.

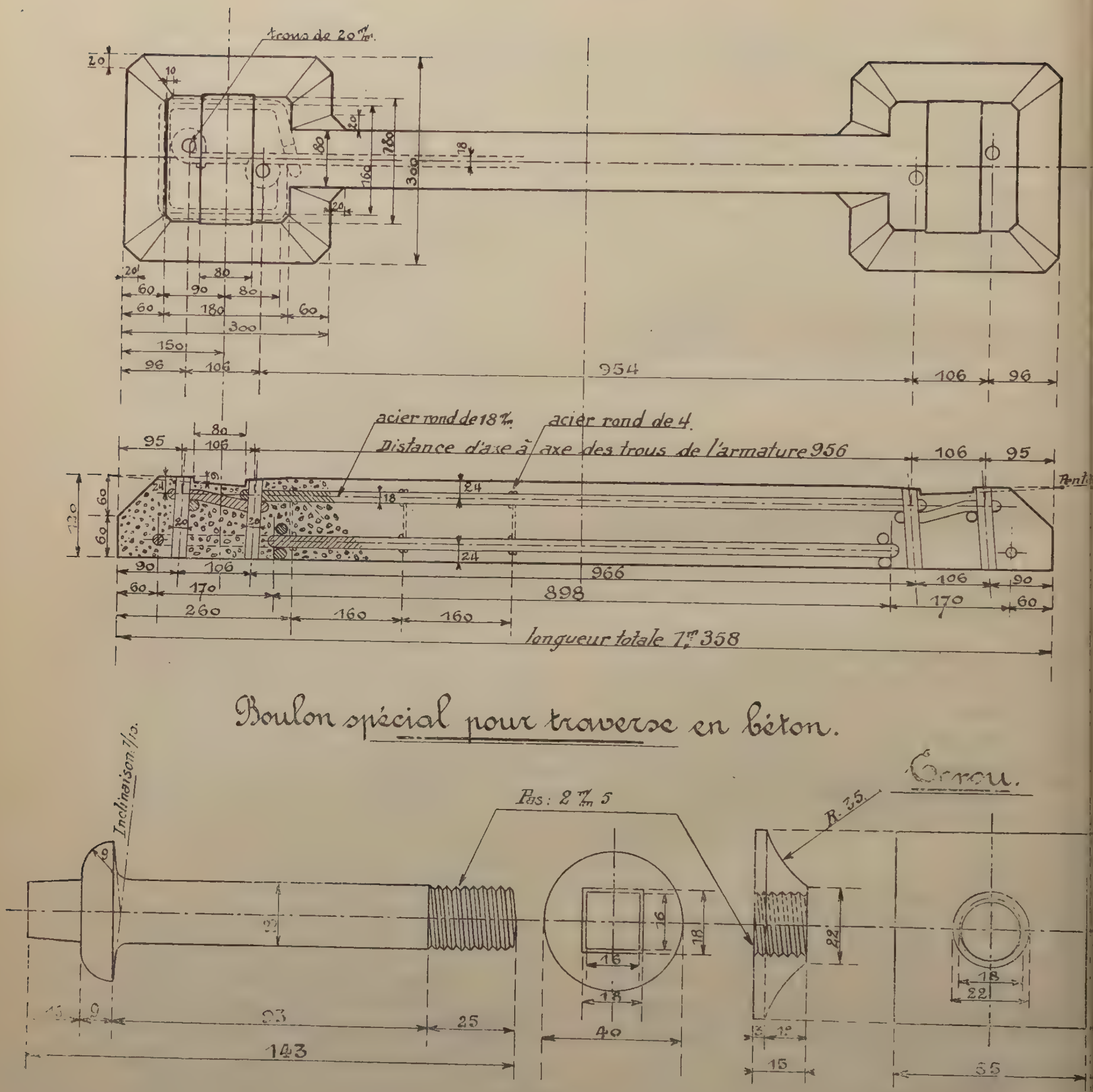


Fig. 17.

Explanation of French terms : Trous de 20 m/m. = Holes of 25/32 inch. — Acier rond de 18 m/m. (de 4 m/m.) = Round steel 11/16 (5/32) in. — Boulon spécial pour traverse en béton = Special bolt for concrete sleepers. — Distance d'axe en axe, etc. = Distance from axis to a[xis] of the holes in the reinforcement (3 ft. 1 5/8 in.). — Ecrou = Nut. — Longueur totale 1m358 = Total length 4 ft. 5 23/64 in. — Pente 1 [: 20] = Inclination 1 : 20.

The switch and the crossings are connected by rails of suitable lengths.

The switch is single or double according to whether the line divides into two or three branches.

The double switches, which are for three lines, show the following varieties :

1. Double switches properly so-called with two stock rails and four tongues, two long ones and two short ones in juxtaposition [fig. 18 (1)];

2. Double switches containing in reality two successive single switches, which are very close together, with four stock rails and two pairs of tongues, placed one behind the other [fig. 18 (2)].

The second one has the drawback that the two frogs A. A. are on the same line at right angles to the axis of the through line and are crossed over at the same time by the two wheels of the same axle; therefore there occurs considerable vertical shock if these components are traversed at high speed which must, if possible, be avoided.

The crossing permits one line to cut across another on the same level. It is at right angles or oblique.

There furthermore exist slip points, also called English crossings. This is a crossing with a tongue which allows either to cross a line on the level or to pass from one line to another. These components are single or double according to whether they work in two or four directions.

A great number of companies have installed one single type of crossing which is adapted for right and left and double curve deviations, the advantage of which is a simplification of stock.

Most companies build up their switches and crossings from the same type of rails as in the running track.

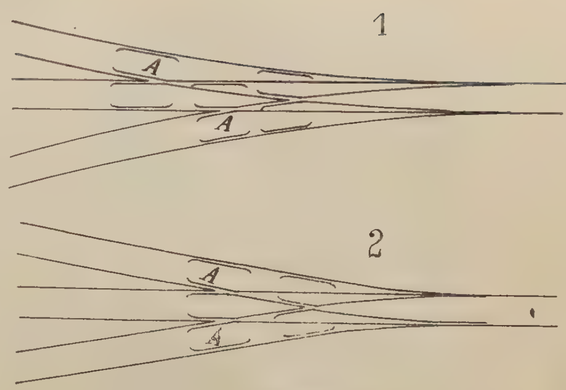


Fig. 18.

The tongue is generally made either from a rail, the foot of which is planed, or planed from a bar of rectangular section.

The length of the tongue varies from 5 to 3 m. (16 ft. 5 in. to 9 ft. 10 1/8 in.).

The two rails of the crossing meet at an angle which varies with the layout of the line from which arises the necessity of having several types, the number of which, for light railways, can be limited to two or three.

The usual method of defining a crossing is to give the angle in degrees, minutes and seconds or the tangent of this angle.

These tangents vary for ordinary track which is passed over at a good speed, between 1 in 5 and 1 in 10. In special cases and in stations and yards, crossings of 1 : 3.5 or 1 : 4 are sometimes used.

The frog is often made of rails which are joined to one another by bolts or by rivets.

Cast iron frogs are only found exceptionally, but one finds frogs of cast steel, often heat treated in order to increase their hardness.

During the last few years, frogs of special manganese steel have begun to be used.

The problem which the engineer must solve is that of supplying a sufficiently hard, homogeneous, durable metal which, however, can be machined readily and which can support the loads usually placed on a steel rail, taking into account the fact that the butting face at the point of intersection of the gaps is reduced by 70 to 80 % and that on the point of the frog the normal load is concentrated on about 10 to 20 % of the butting face. This means that the point must support a load which is 5 to 10 times greater per square centimetre than the other parts of the frog.

One of the great difficulties of working pieces of mangenese steel is the problem of shrinkage. When one considers that a piece of this kind of steel 6 m. (19 ft. 8 1/4 in.) in length at a temperature of 1 350° C. (2 462° F.) loses 0.15 m. (6 inches) at the normal temperature, it is evidently necessary to take precautions in order to obtain the required profile, taking into account the shrinkage, and to layout all the drawings carefully, in order to avoid fissures which may occur between parts which show too great differences of thickness (1).

For many years tramway companies have made use of it and are very well satisfied. It is true that they have a more immediate interest in using them because the question of upkeep and renewals plays a more important part than with light railway companies. In fact the price of the components is relatively high and the question of using them resolves itself into an economic question. One has to figure on one side the cost of the equipment and its amortisation and on the other the expense of upkeep and renewal of the ordinary crossings.

The *Société des Transports en Commun de la Région Parisienne* and the *Société nationale des chemins de fer vicinaux (Belgium)* largely use these components in manganese steel and they have given entire satisfaction. The chief characteristics of manganese steel are its great tensile strength and its very great resistance to wear through friction. The contents of manganese ean vary from 10 to 14 % and the carbon must reach about 1 %.

An inconvenience came to light however when it was a question of repairing the frog or when one desired to weld to the next rails. The difficulty of working this steel then showed itself. The makers, therefore, looked for a special steel which, whilst being entirely weldable, combined all the qualities of manganese steel. These results were obtained with chrome-nickel steel.

In America they have begun to use chrome-nickel steel for the crossings of the turnouts. Cast steel is generally used. The steel used consists of an alloy containing 2.75 % of nickel, 0.80 % of chrome and 0.50 % of carbon, and offers a resistance to fracture of 75 kgr. per mm² (47.6 Engl. tons per square inch.) with an elongation of 12 %. This gives a metal which is easily machined and which can be welded by the thermit process without changing appreciably its wear-resisting qualities.

In the maufacture of pieces with chrome-nickel almost the same difficulties of moulding and casting are found as when making details in manganese steel : the shrinkage however is less.

The *Société nationale des chemins*

(1) Extract from a paper on the manufacture and the employment of chrome-nickel steel read by Mr. E. B. Entwisle at the International Tramways & Light Railways Congress in Rome in 1928.

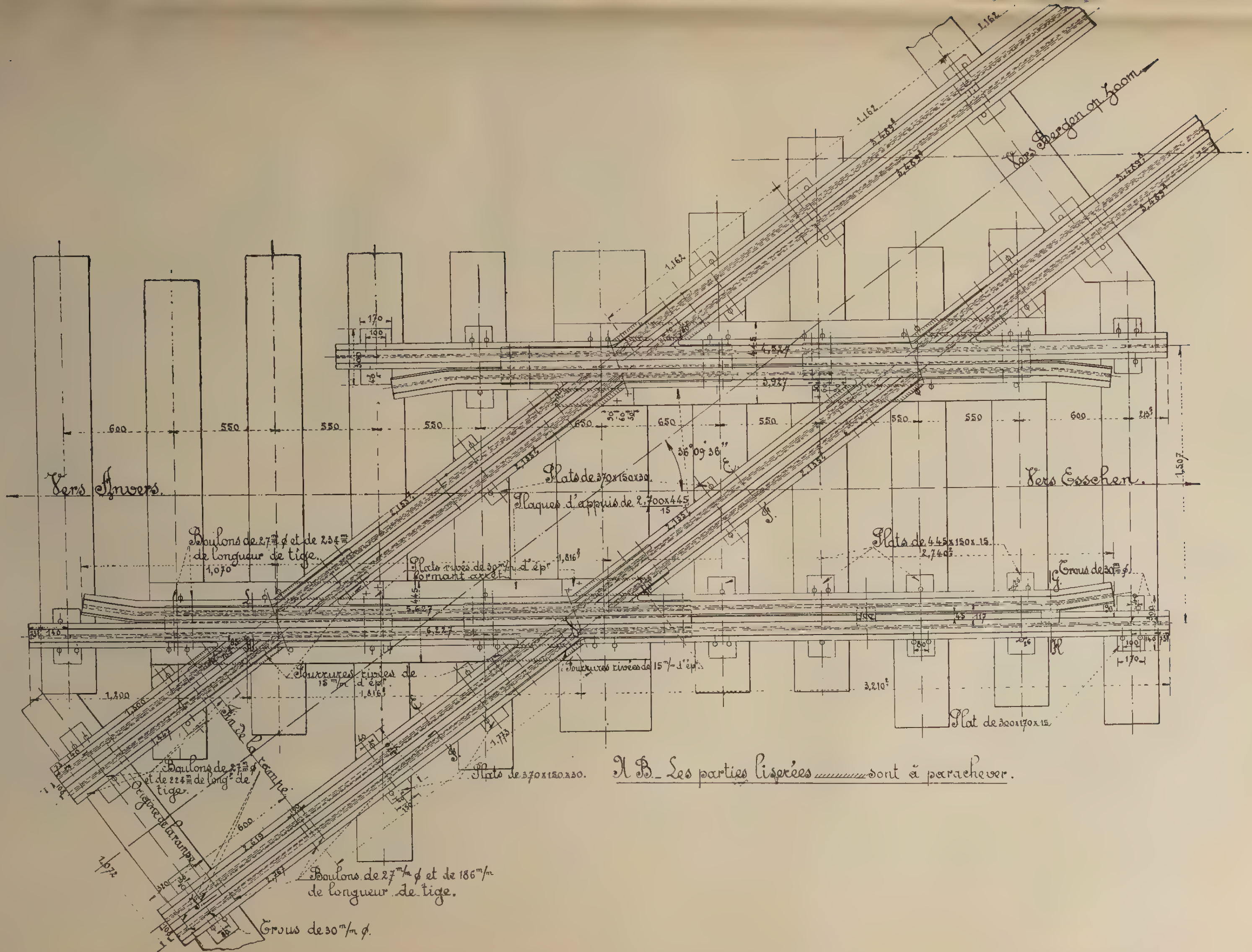


Fig. 19. — Crossing to be provided at the level crossing No 25 (near the station of Capellen) on the line from Antwerp to Esschen.

For explanation of French terms see page 2188.

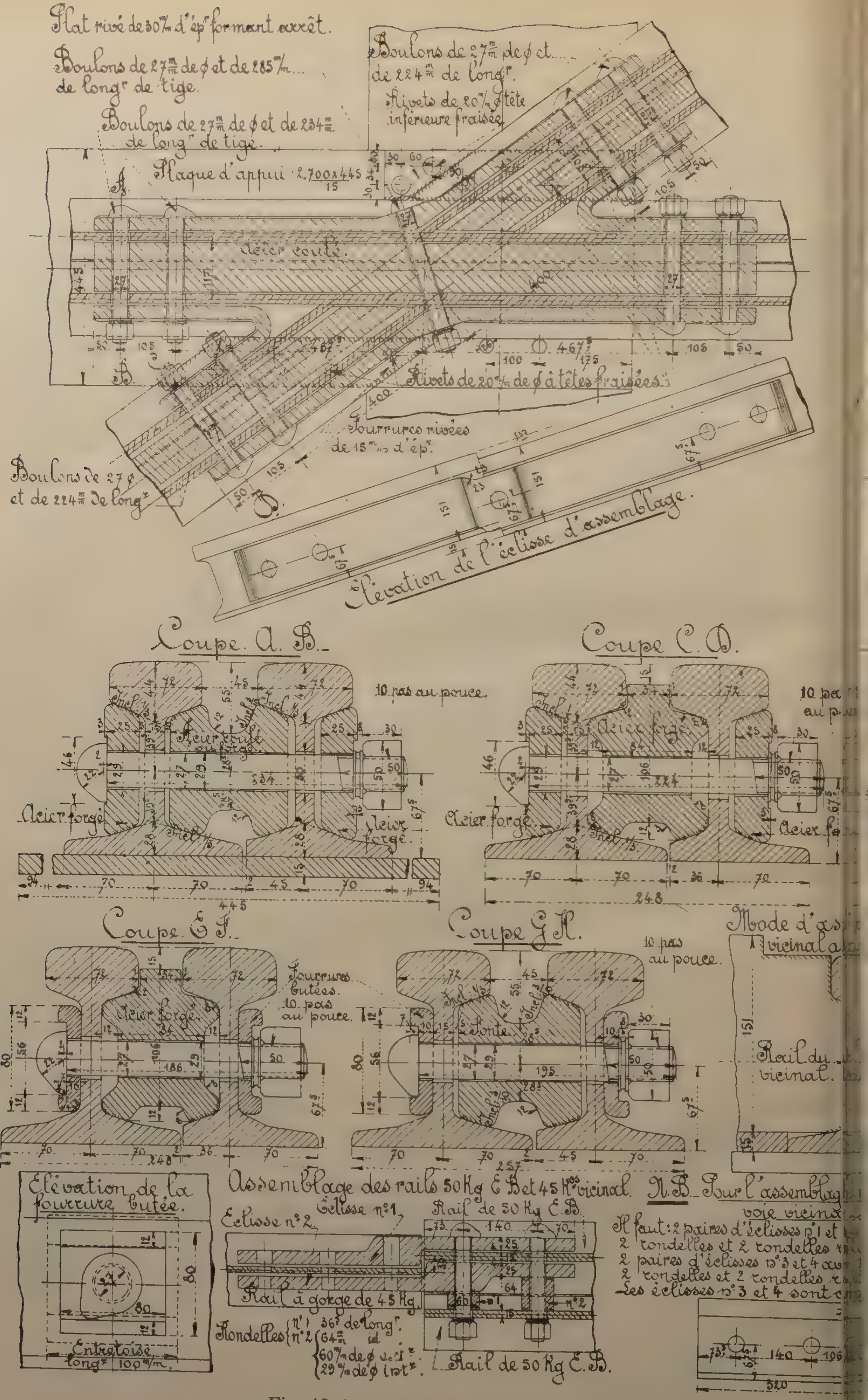
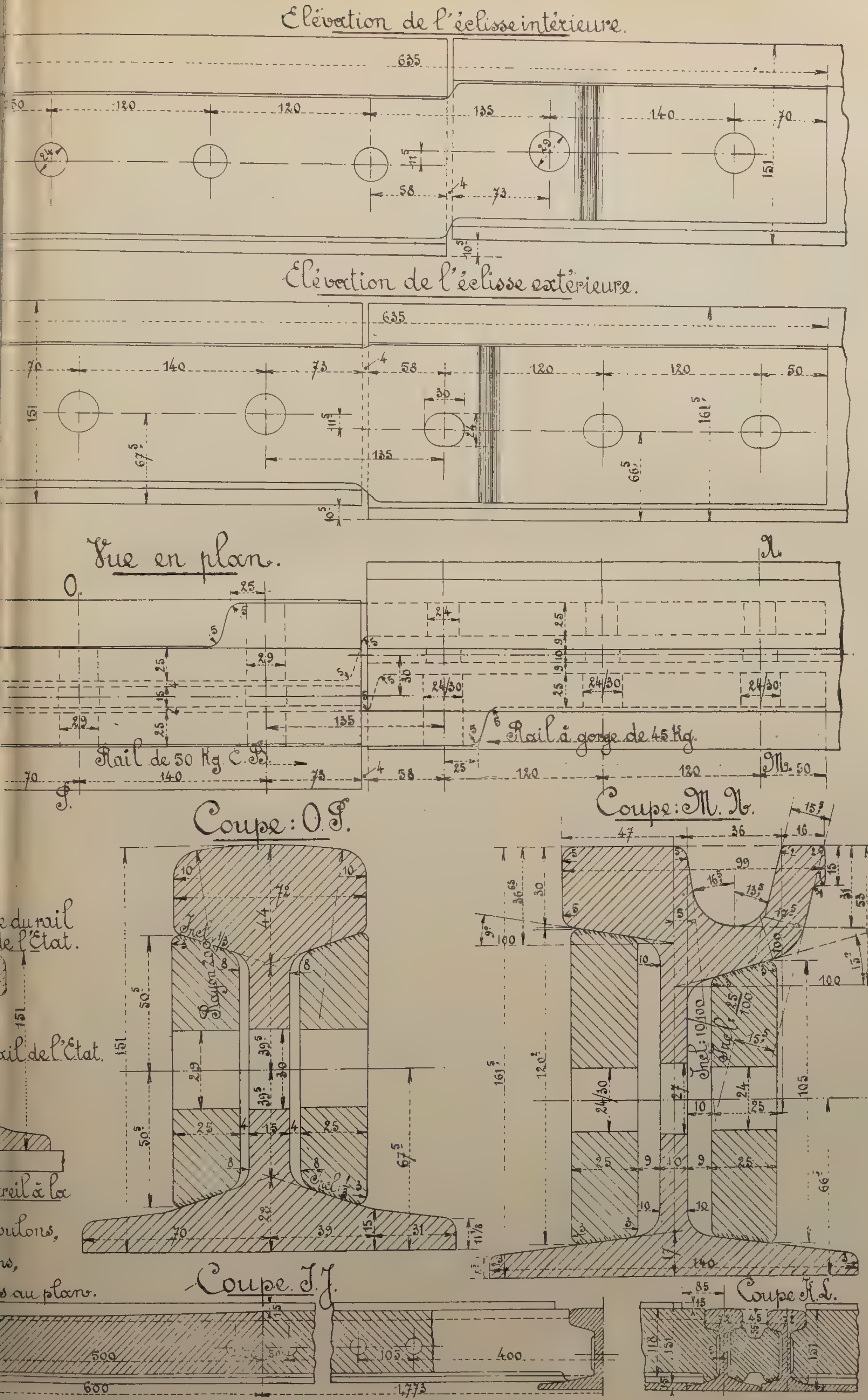


Fig. 19 (*continued*). — Crossing to be provided at the level crossin



(near the station of Capellen) on the line from Antwerp to Esschen·

Explanation of French terms in figure 19.

Page 2185.

Boulons de 27 mm. etc. = Bolts of 27 mm. dia. and 234 mm. long. — Fin de la rampe = End of rise. — Fourrures rivées de ... mm. = Rivetted packing pieces ... mm. thick. — Origine de la rampe = Beginning of rise. — Plaques d'appui = Supporting plates. — Plats de ... mm. = Flats ... mm. thick. — Plats rivés de 30 mm. d'épaisseur formant arrêt = Rivetted flats 30 mm. thick to form a stop. — Trous de ... mm. ∅ = Holes of ... mm. diameter. — Vers Anvers. = To Antwerp. — Vers Bergen op Zoom = To Bergen op Zoom. — Vers Esschen. = To Esschen. — *N. B.* Les parties liserées etc. = The parts marked ....must be carefully finished.

Pages 2186 and 2187.

Acier coulé = Cast steel. — Acier forgé = Wrought steel. — Assemblage des rails 50 kgr. E. B. et 45 kgr. vicinal. = Assemblage of rails, 100.8 lb. (Belgian State) and 90.7 lb. Local. — Boulons de ... mm. de ∅ et de . . mm. de long. = Bolts ... mm. diameter....mm.long. — Coupe = Cross section. — Eclisse = Fishplate. — Elévation de l'éclisse d'assemblage = Elevation of double junction plate. — Elévation de la fourrure butée = Elevation of adjusting piece. — Elévation de l'éclisse extérieure. — Elevation of outer fishplate. — Elévation de l'éclisse intérieure = Elevation of inner fishplate. — Entretoise longueur 100 mm. = Connecting beam 100 mm. long. — Fourrure butée = Adjusting piece. — Fourrure rivée etc. = Rivetted adjusting piece 15 mm thick. — Inclinaison 1/3 = Inclination 1 : 3. — Mode d'assemblage du rail vicinal. Method of securing the Light railway rail to the Belgian State Railway rail. — Plaque d'appui. — Supporting plate. — Plat rivé de 30 mm. formant arrêt = Rivetted flat iron 30 mm. forming a stop. — Rail à gorge de 45 kgr. = 90.7 lb. per yard grooved rail. — Rail de l'Etat — State Railway rail. — Rail de 50 kgr. E. B. = Rail of 100.8 lb. per yard (Belgian State). — Rail de 45 kgr. = Rail of 90.7 lb. per yard. — Rail du vicinal = Light railway rail. — Rayon = Radius. — Rivets de 20 mm. de ∅ etc. = Rivets 28 mm. diameter with milled heads. — Rondelles = Washers. — Vue en plan = Plan. — 10 pas au pouce = 10 threads per inch. — *N. B.* — Pour l'assemblage de l'appareil à la voie vicinale il faut : 2 paires etc. = *N. B.* — For assembling the crossing on light railway track there are required 2 pairs of fishplates No. 1 and 2 with bolts, 2 washers and 2 spring washers, 2 pairs of fishplates 3 and 4, with 2 bolts, 2 washers and 2 spring washers. The fishplates No. 3 and 4 are contrary to plan.

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de fer vicinaux (Belgium) is at present making experiments with turnouts (tongues and crossings) of cast chrome-nickel steel which has the following characteristics :

Resistance : 90 to 100 kgr. par mm^2 (57.1 to 63.5 Engl. tons per square inch) ;

Elongation in 100 mm. (3 15/16 inch) : 15 to 10 % ;

Resiliency : 6 to 12 Kg.-M. (43.4 to 86.8 foot-pounds) ;

Elongation limit : 70 to 90 kgr. (44.4 to 57.1 Engl. tons per square inch) ;

Resistance to repeated impacts, hammer of 2.300 kgr. (5.070 lb.) at 4 cm. (1 9/16 inches), cast Cambridge shape test piece with a test for alternative (180°) impact stress, one blow per second : 5 to 10 times the resistance shown by rolled Bessemer steel.

The price of points and crossings in chrome-nickel steel does not differ appreciably from that in manganese steel.

They expect to obtain most encouraging results. They have had them in use for four years in a track subjected to much traffic, without finding the slightest wear.

Crossings.

When a main line with dense and fast traffic is crossed by a secondary line with slower traffic or by a shunting line over which the vehicles move at slow speed, one can, in order to traverse these lines, limit oneself to simply cutting the rails of the secondary lines or of the shunting lines, maintaining the complete continuity of the rails of the main line. The main line therefore does not undergo any alteration and there is no reason to make

its trains reduce speed. But it is evident that in this case the rails of the traversing line must be raised in order to allow the flanges of the wheels to cross over the top of the other line. Figure 19 shows the arrangement of a crossing of this kind in use at the crossing of the line of the *Belgian National Railway Company* and one of the *Société nationale des chemins de fer vicinaux (Belgium)* and designed by the first of these companies.

In cases where the above arrangement cannot be used, crossings made of rails rigidly assembled together and strongly secured to a timber foundation have been used. Notches are provided at the intersections of the rails for the passage of the wheel flanges. These apparatus break easily and are difficult and costly to keep up. Figure 20 shows a crossing of this kind.

For much used crossings special cast steel parts have been used for a number of years.

The *Société des Transports en Commun de la Région Parisienne* and the *Société nationale des chemins de fer vicinaux (Belgium)* are regularly making use of right angled or oblique crossings of cast manganese steel in the cases where there are frequent trains. They thus avoid too frequent renewals, the cost of laying and removing, and the interruption to the traffic. We give below (fig. 21) a drawing which shows the crossing used by the *Belgian National Railway Company* when crossing a light railway line.

The same two companies are at present making experiments with crossings of chrome-nickel steel which show the same advantages as those obtained with manganese steel, but allow of welding the joint and refilling worn places by the thermit process.

The cost of these components in special steel is high (about two or three times the price of ordinary equipment) but they last much longer than those made from rails (seven to ten times as long). As a result of their greater rigidity, their use may be considered economic in all cases of intensive traffic.

SUMMARY.

The result of these investigations is as follows :

Axle loads of the stock is increasing more and more, necessitating well made, dry, and well drained earthworks, and a much stronger and more solid permanent way.

Any gauge of track can be suitable according to local circumstances.

Equally, the choice of traction is a matter of convenience.

The Vignoles rail which is almost exclusively used in the lines laid beside high roads or on special earthworks, has the following average characteristics :

Gauge of track 1.435 m. (4 ft. 8 1/2 inches): height 140 mm. (5 1/2 inches); width 130 mm. (5 1/8 inches); head 60 mm. (2 3/8 inches), of an average linear weight of 38 kgr. (76.6 lb. per yard). Metre gauge : height 113 mm. (4 7/16 inches); width 90 mm. (3 1/2 inches); head 45 mm. (1 3/4 inches), of an average linear weight of 23 kgr. (46.4 lb. per yard) for the lines worked by steam; and of 125 mm. (5 inches) height, 105 mm. (4 1/8 inches) width, 57 mm. (2 1/4 inches) head, of an average linear weight of 32 kgr. (64.5 lb. per yard for those worked electrically.

The length of the rails varies generally between 9 and 18 m. (29 ft. 6 3/8 in. and 59 ft. 5/8 in.) with a tendency towards the latter figure.

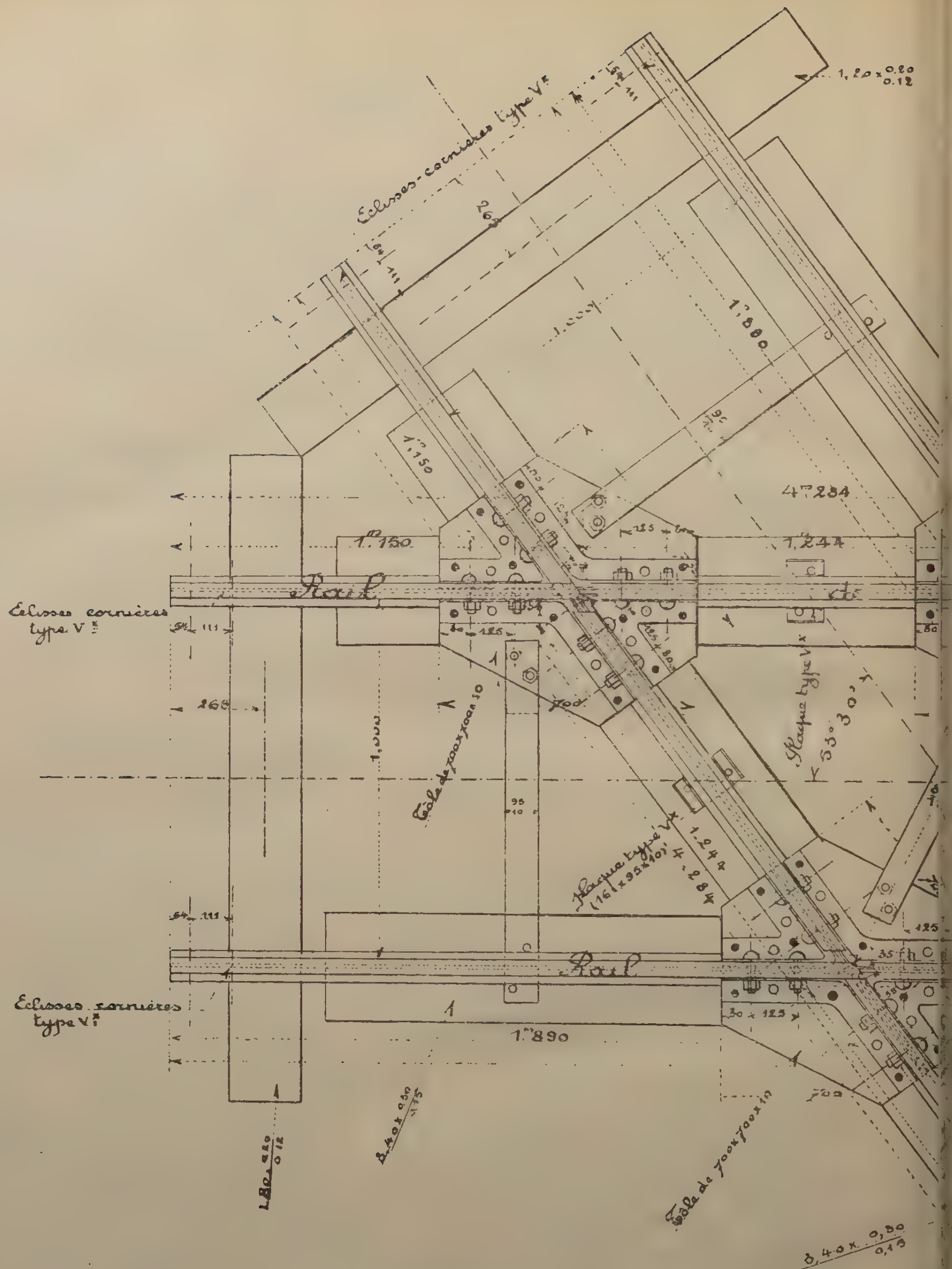
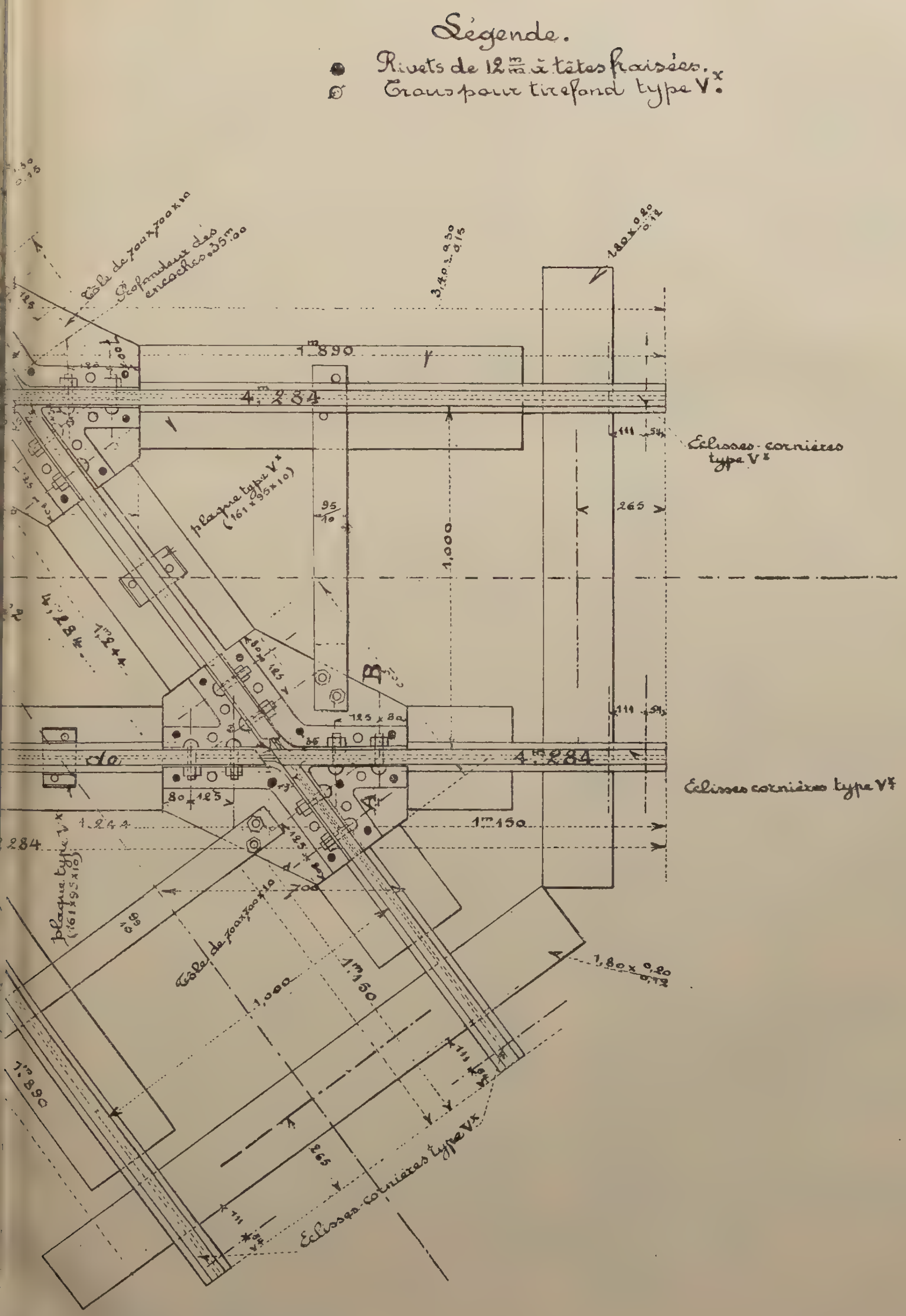


Fig. 20. — Crossing on lines laid alon

Explanation o



igh road. — General arrangement plan.

erms see page 2193.

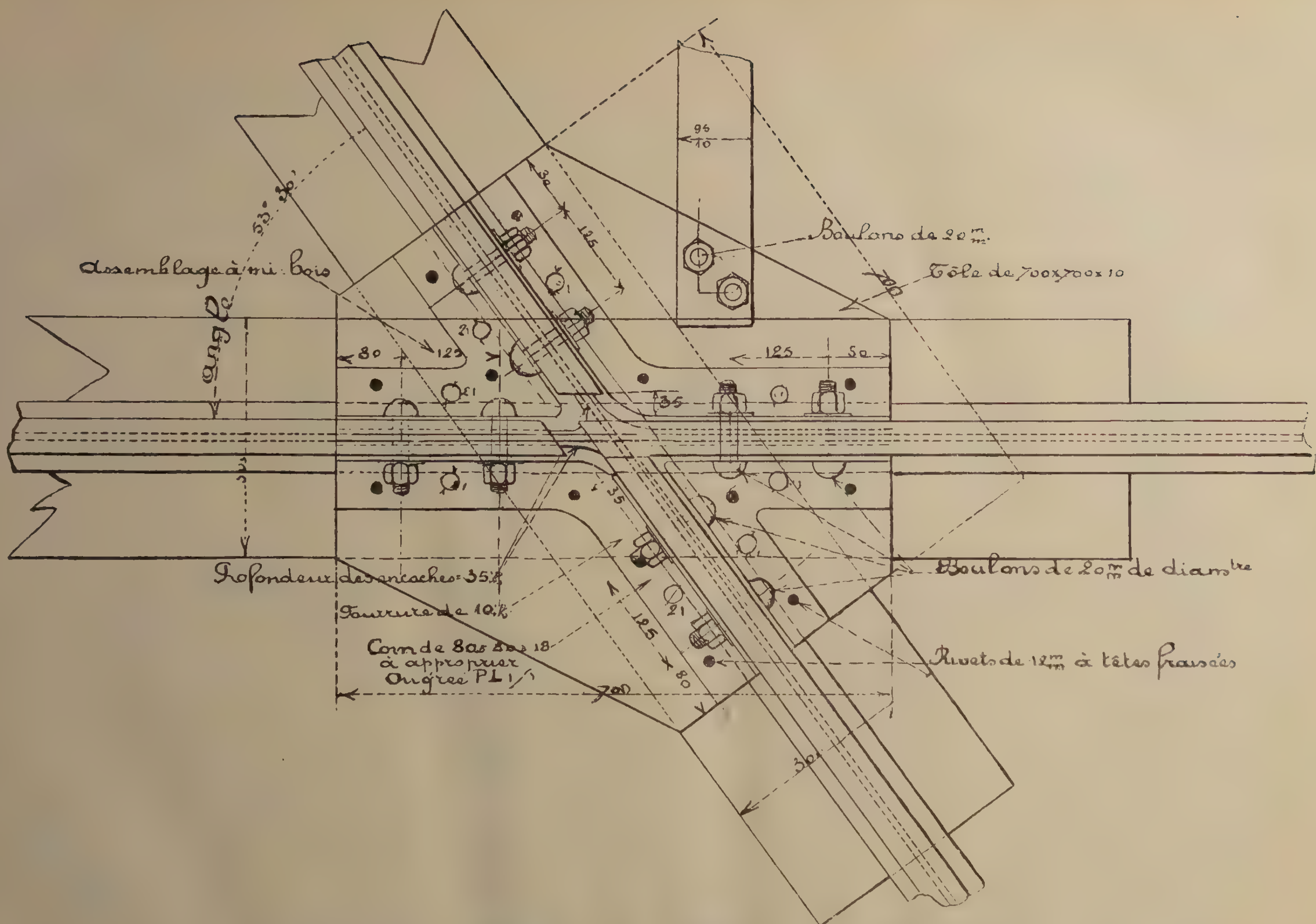


Fig. 20 (*continued*). — Crossing on lines laid alongside a high road. — Detail of a crossing.

Explanation of French terms : see page 2193.

Explanation of French terms in figure 20.

Pages 2190 and 2191.

Tôle de = Iron plate of ... mm. = Plaque type Vx = Plate type Vx — Légende : ● Rivets de 12 mm. à têtes fraisées. ∅ Trous pour tirefond type Vx = Explanation : ● 15/32-inch rivets with milled heads. — ∅ Holes for coachscrews type Vx. — Eclisses cornières type Vx = Angle fishplates type Vx. — Profondeur des encoches = Depth of the notches.

Page 2192.

Assemblage à mi-bois = Scarfed joint assembly. — Angle de 53° 30' = Angle of 53° 30'. — Profondeur des encoches = Depth of the notches. — Fourrure de 10 m/m = 3/8-inch gauge clip. — Coin de bois 80 × 80 × 18 à approprier = Angle of 80 × 80 × 18 mm. to fit Ougrée PL 1. — Boulons de 20 mm. = Bolts 25/32-inch diameter. — Tôle de ..... = Iron plate 700 × 700 × 10 mm. — Rivets de 12 mm. à têtes fraisées = Rivets 12 mm. with milled heads

There is a marked preference for leaving the top of the sleepers free from ballast in view of the easier inspection and maintenance of the rail fastenings.

The choice of the kind of ballast is chiefly guided by economic reasons, although it is recognized that broken stone constitutes the best ballast.

Corrugated wear of rails only shows itself to a small extent on light railways. The remedy for this trouble can be found in the use of a good and homogeneous steel with a high tensile strength, a high elastic limit and the highest possible elongation. These different characteristics must be in suitable proportions to each other.

The laying of the track is done with opposite joints on the straight, staggered joints being used only when laying in curves of a radius generally smaller than 100 m. (5 chains).

Creep is hardly apparent in light railways. It is overcome either by the fixing of angle fishplates to the sleepers, or by stirrups which are fixed to the rails and the sleepers, or simply by stirrups against the heads of the coachscrews.

Frequently, the rails are laid at an inclination on the sleepers. This cant is obtained either by adzing the sleepers or by the shape of the sole plate or the chair. The first mentioned system is, however, the more generally used.

The fish plates of the rails are becoming simpler and generalized by the angle fishplate with four or six bolts; the loosening of these is chiefly prevented by spring washers, Grover type, or by tension plates.

Grooved or twin rails are used on the inner line of curves of a small radius. In this case the use in the outer line, of rails made of high tensile steel or special steels (manganese and chrome-nickel) is recommended.

Barberot keys can be used with economy on the outer rails of small curves.

The use of sleepers is general. Sleepers of oak, or pine impregnated with creosote, are the most used.

The rails are fastened to the wooden sleepers by means of coachscrews either direct or in conjunction with steel sole plates, without marked preference for either system.

When metal sleepers or ferro-concrete sleepers are used, the fastening of the rail is usually by means of clips and bolts.

The metal sleeper has advantages as regards duration and the security of the fastenings; it is not however extensively used.

Concrete sleepers are being increasingly used, although they are costly and rather

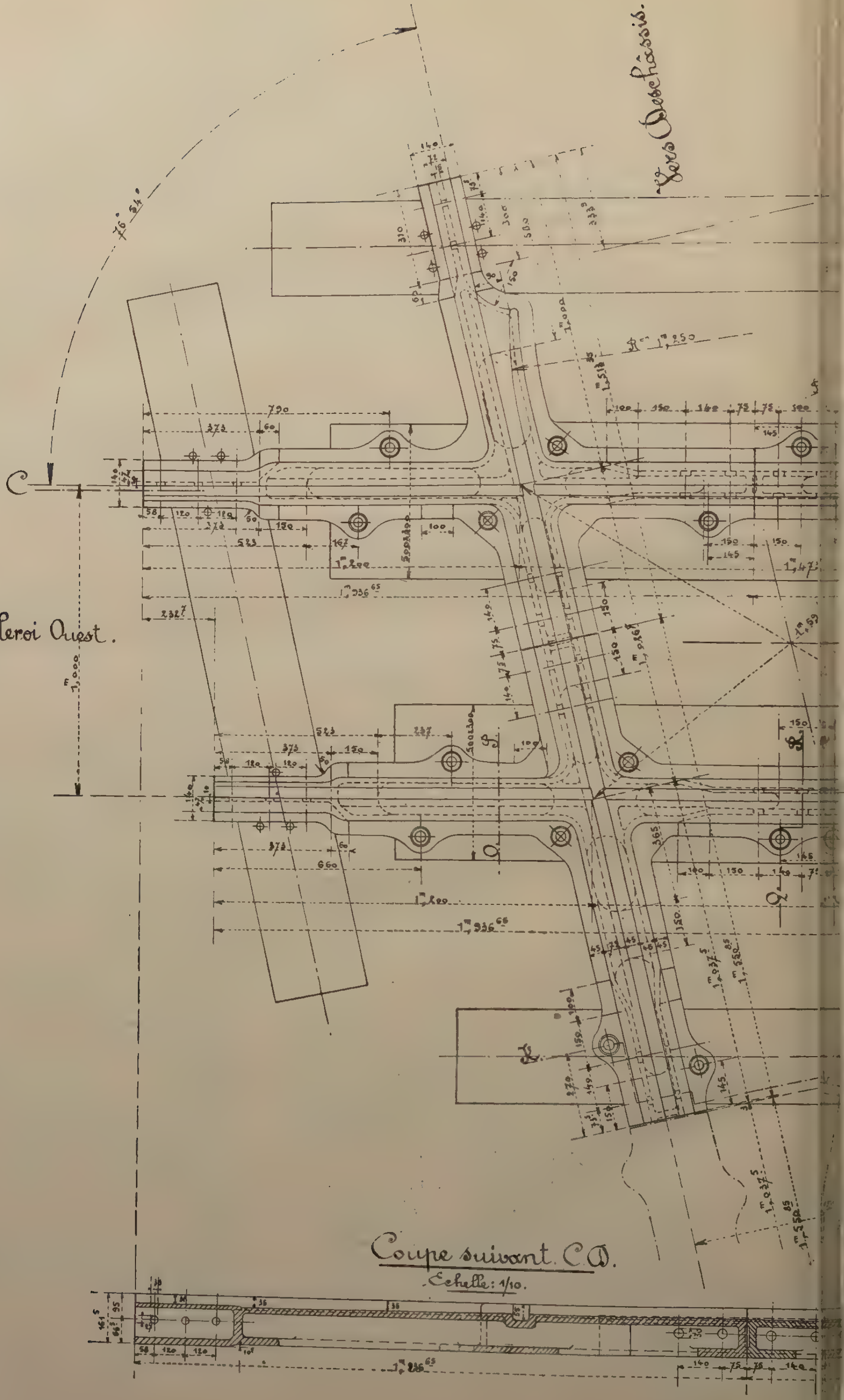
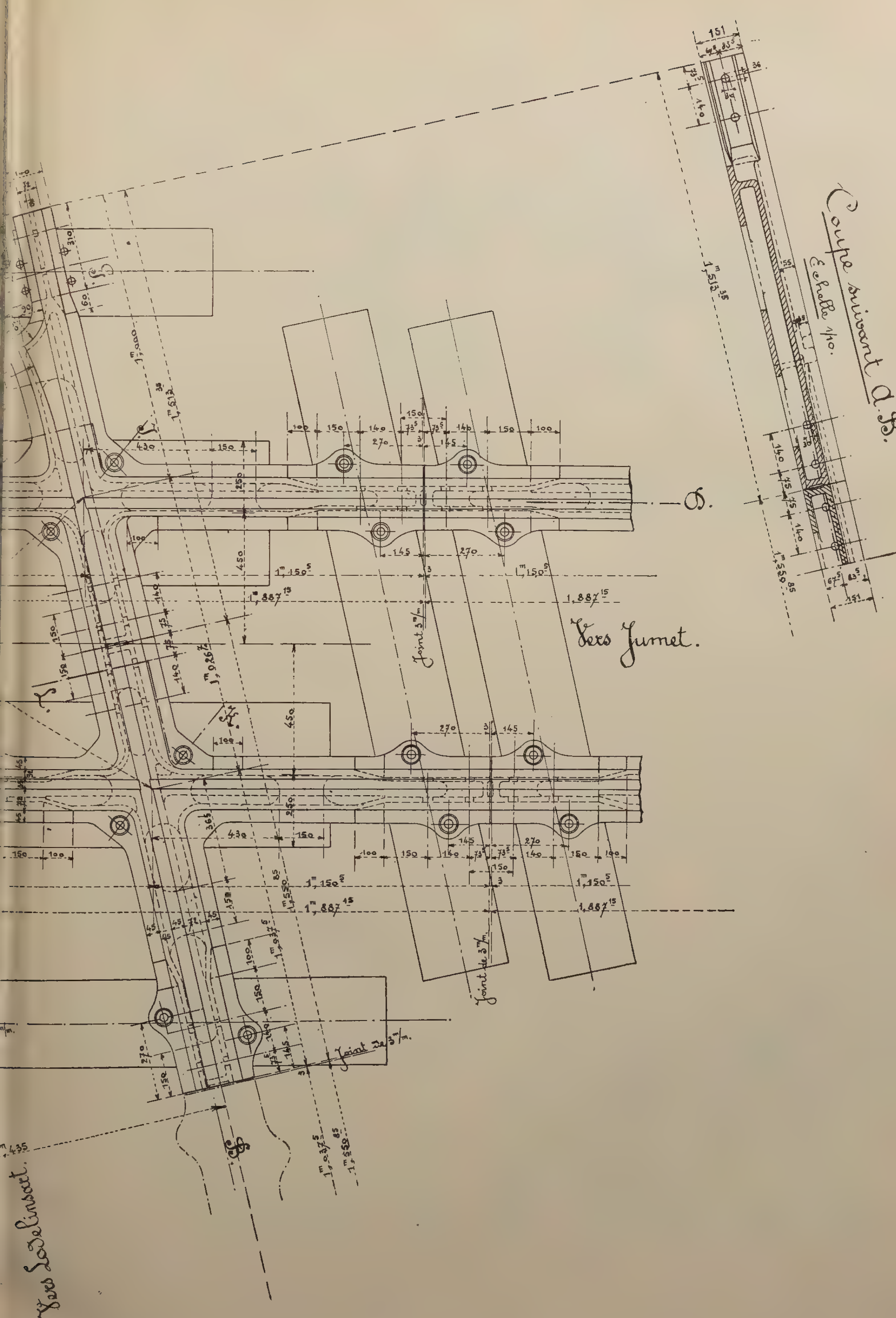

Vers Deschassis.
Vers Charleroi Ouest.
76° 54'
Coupe suivant C.D.
Echelle: 1/10.

Fig. 21. — Level[illegible]



made of manganese steel.

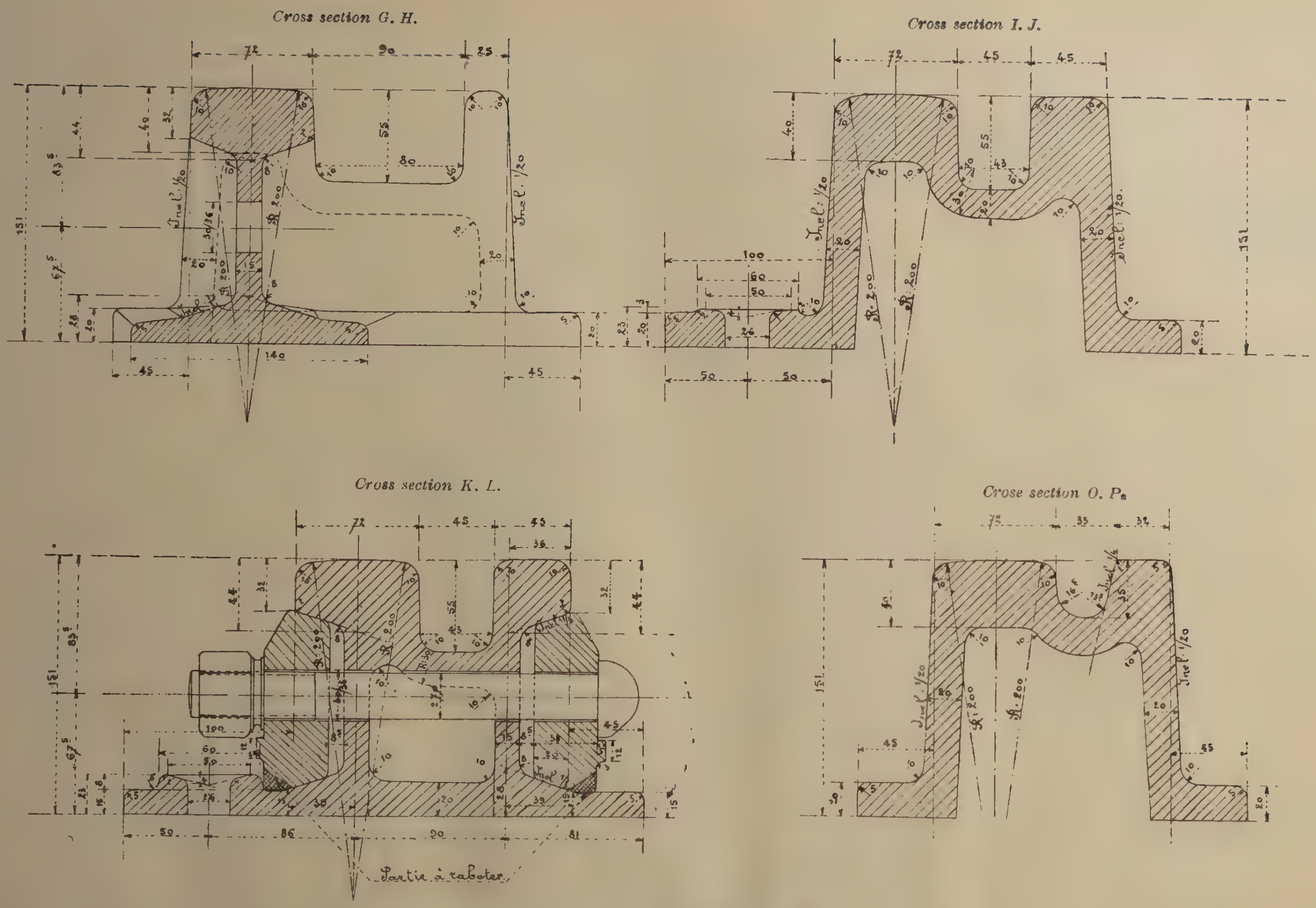


Fig. 21. — Level crossing made of manganese steel (*continued*).

Cross section Q. R.

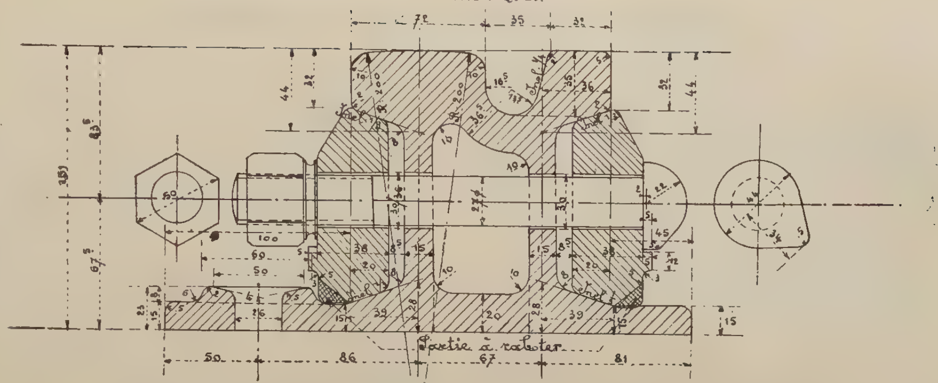


Fig. 21 (*continued*). — Level crossing made of manganese steel.

Explanation of French terms : Echelle 1/10 = Scale 1 : 10. — Incl. 1/3 (1/4, etc.) = Inclination 1 : 3 (1 : 4, etc.) — Partie à raboter = Part to be planed. — Vers Charleroi-Ouest (Deschassis, etc.) = To Charleroi Ouest (Deschassis, etc).

difficult to handle. The type consisting of two supports with large bearing surface joined by a small metal tie bar or by ferro-concrete bar is generally preferred. It gives very encouraging results.

The welding of rails is not yet general practice.

Experiments made on a large-scale and of long duration show, however, the considerable advantages which can be obtained therefrom and encourage the development of its use.

Thermit welding has up to now only been employed for new lines; arc welding for old rails, repairs to points and crossings and building up of rail ends.

The process generally adopted when electrically welding rails consists in welding the fishplates to the rails, to stiffen up the joint by a plate welded under the foot and to weld the heads of the rails together.

Electric welding of the rails end to end without fishplates is, however, developing, and it would be interesting to see it continued in view of the encouraging results obtained during the experiments.

The limit, as regards length, of the parts of the line to be welded on special site or beside high roads is a matter of the temperature fluctuations in the district. For a temperature fluctuation of 60° C. (108° F.) the welded length can go up to 60 m. (197 feet) without inconvenience.

The use of heat treated cast steel in the manufacture of crossings is developing and gives very satisfactory results.

The experiments with special manganese or chrome-nickel steel for the manufacture of parts subjected to much strain (crossings and cross overs) have given entire satisfaction from the economic point of view as well as from that of wear.

Summary of replies to the list of questions.

1. *The County Donegal Railways Joint Comittee (Ireland).* — Length of track: 201 km. (125 miles); gauge 1.067 m. (3 ft. 6 in.). Steam traction. Uncovered sleepers. Vignoles rails 27 kgr. (54.4 lb. per yard) in lengths of 13.71 m. (45 feet). Cant by adzing the sleepers. Flat fishplates. No welding. Sleepers of creosoted pine. Rails laid direct on sleepers.

2. *Société Anonyme des Voies ferrées des Landes (France).* — Length of track: 363 km. (225.6 miles); gauge 1.445 m. (4 ft. 5 7/8 in.). Steam traction. Covered sleepers. Vignoles rails 25 kgr. (50.4 lb. per yard) in lengths of 8 to 16 m. (26 ft. 3 in. to 52 ft. 6 in.). Cant of rail by adzing the sleepers. Grover washers. No welding. Pine sleepers impregnated with sulphate of copper, and of untreated oak. Rails laid direct on sleepers. Experiments with poplar sole plates.

3. *Berner Alpenbahn, Bern-Loetschberg-Simplon (Switzerland).* — Length of track : 1 541 km. (957 miles); gauge 1 metre. Steam and electric traction. Vignoles rails 20 to 30 kgr. (40.3 to 60.5 lb. per yard. Oak, beech and pine sleepers.

4. *Compagnie des Tramways de l'Indre (France).* — Length of track : 182 km. (113.1 miles); gauge 1 metre. Steam and petrol motor traction. Sleepers uncovered between rails. Vignoles rails of 18 kgr. (36.3 lb. per yard) in lengths of 10.8 to 11 m. (35 ft. 5 in. to 36 ft. 1 in.). Cant of rail by adzing the sleepers. Twin rails in the curves of small radius. Flat fishplates for 4 bolts. No welding. Sleepers of untreated oak. Experiments with concrete sleepers were abandoned on account of the high price. Rails laid direct on the sleepers.

5. *Compagnie des Tramways départementaux des Deux-Sèvres (France).* — Lengh of track: 195 km. (121.2 miles); gauge 1 metre. Steam and petrol motor traction. Ballast usually level with the top of the sleepers. Vignoles rails of 22 kgr. (44.3 lb. per yard) in lengths of 10 m. (32 ft. 9 3/4 in.). Cant of rail by adzing the sleepers. Twin rails in the curves of small radius. Flat and angle fishplates for 4 bolts. No welding. Sleepers of untreated oak. Ferro-concrete sleepers under test for the last three years. Rails laid direct on the sleepers.

6. *Compagnie générale de Voies ferrées d'intérêt local, Paris (France).* — Length of track: 668 km. (415.1 miles) of which 213 km. (132.4 miles) of 1.44 m. (8 ft. 8 7/8 in.) gauge and 455 km. (282.7 miles) of 1 metre. Steam traction and some petrol motors. Uncovered sleepers except beside high roads. Vignoles rails of 20, 25 or 30 kgr. (40.3, 50.4 or 60.5 lb. per yard) in lengths of 8, 11 and 12 m. (26 ft. 3 in., 36 ft. 1 in. and 39 ft. 4 1/2 in.). Cant of rails by adzing the sleepers. Flat and angle fishplates for 4 bolts. Grover washers. No welding. Untreated oak sleepers. Recent experiments with metal sleepers type U. V. F. Rails laid direct on the sleepers.

7. *Compagnie des Chemins de fer du Sud-Ouest (France).* — Length of track : 406 km. (252.3 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignole rails 18, 20 and 26 kgr. (36.3, 40.3 and 52.4 lb. per yard) in lengths of 11 and 12 m. (36 ft. 1 in. and 39 ft. 4 1/2 in.). Cant of rails by adzing the sleepers. Flat fishplates for 4 bolts for rails of 18 and 20 kgr. Angle fishplates for 4 bolts for rails of 26 kgr. Grover washers. No welding. Sleepers of creosoted oak. Rails laid direct on sleepers

8. *Northern Counties Committee, London, Midland & Scottish Railway Company, Belfast (Ireland).* — Length of track: 103 km. (64 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignoles rails of 18.5 to 31.6 kgr. (37.5 lb. to 62.5 lb. per yard) in lengths of 6.40 m. to 9.15 m. (21 to 30 feet). Twin rails in curves of small radius up to 30 m. (1 1/2 chains). Angle fishplates for 6 bolts. Ibbotson nuts. No welding. Sleepers of cresoted pine or fir. Rails laid direct on sleepers.

9. *Chemins de fer secondaires du Nord-Est (France).* — Length of track: 782 km. (485.9 miles) of which 312 km. (193.9 miles) of 1.445 m. (8 ft. 8 7/8 in.) gauge, 244 km. (151.6 miles) of metre gauge, and 226 km. (140.4 miles) of 0.60 m. (2-foot) gauge. Steam and petrol motor traction. Uncovered sleepers. Vignoles rails of 15 to 30 kgr. (30.25 to 60.5 lb. per yard) in lengths of 8, 11 and 12 m. (26 ft. 3 in., 36 ft. 1 in. and 39 ft. 4 1/2 in.). Cant of rail by adzing the sleepers. Barberot packing on curves of a radius of less than 100 m. (5 chains) or 150 m. (7 1/2 chains). Generally flat fishplates with 4 or 6 bolts. Grover washers. No welding. Oak sleepers impregnated with cold carbonyle during 24 to 48 hours. Experiments with light metal sleepers, type U. V. F. Rails laid direct on the sleepers.

10. *Chemins de fer et Minières Prince-Henri, Luxembourg.* — Length of track: 65 km. (40.4 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignoles rails of 26.1 kgr. (52.5 lb. per yard) in lengths of 10 and 12 m. (32 ft. 9 3/4 in. and 39 ft. 4 1/2 in.). Cant of rail obtained by the shape of the soleplate. Heeled angle fishplates with 4 bolts. No welding. Sleepers of creosoted oak. Soleplates.

11. *Netherlands Railways (Holland).* — Length of track : 298.4 km. (185.5 miles); gauge 1.435 m. (4 ft. 8 1/2 in.). Steam and petrol motor traction. Covered sleepers. Vignoles rails of 33.5 kgr. (67.5 lb. per yard) in lengths of 15 m. (49 ft. 2 1/2 in.). Cant of rails obtained by the shape of the soleplate. Twin rails in curves with a radius up to 100 m. (5 chains). Heeled angle fishplates for 4 bolts. Grover washers. No welding. Sleepers of oak, beech and creosoted pine (Rueping system). Soleplates.

12. *Chemin de fer du Blanc à Argent, Paris (France).* — Length of track: 190.5 km. (118.4 miles); gauge 1 metre. Steam traction. Covered sleepers. Bull-head rails of 25 kgr. (50.4 lb. per yard), in lengths of 12 m. (39 ft. 4 1/2 in). Cant of rails obtained by the shape of the chairs. Heeled fishplates for 4 bolts. Grover washers. No welding. Sleepers of creosoted pine and non-creosoted oak. Chairs.

13. *Société d'exploitation des chemins de fer en Corrèze (France).* — Length of track: 276 km. (171.5 miles); gauge 1 metre. Steam and petrol motor traction. Uncovered sleepers. Vignoles rails of 20 and 25 kgr. (40.3 and 50.4 lb. per yard) in lengths of 12 m. (39 ft. 4 1/2 in.). Cant of rail obtained by adzing the sleepers. Angle fishplates for 4 bolts. Grover washers. No welding. Sleepers of oak. Metal sleepers in use for the last 24 years. Results very satisfactory. Rails laid direct on the sleeper.

14. *Alsace and Lorraine Railways, including Guillaume-Luxembourg Lines.* — Length of track: 25 km. (15.53 miles) of which 3 km. (1.86 miles) are of 1.435 m. (8 ft. 4 1/2 in.) gauge and 22 km. (13.67 miles) of metre gauge. Steam traction. Uncovered sleepers. Vignoles rails of from 33.4 to 37.8 kgr. (67.3 to 75.2 lb. per yard) in lengths of 9 to 12 m. (29 ft. 6 3/8 in. to 39 ft. 4 1/2 in.). Cant of rail obtained by the shape of the soleplates. Check rails on curves of small radius. Heeled angle fishplates for

6 bolts. Grover washers. No welding. Sleepers of oak and creosoted beech. Soleplates. Use of special steels for the manufacture of turnout frogs.

15. *Société des Transports en commun de la Région parisienne (France).* — Length of track : 1 124 km. (698 miles); gauge 1.44 m. (8 ft. 8 7/8 in.). Steam, electric and petrol motor traction. Covered sleepers. Vignoles rails of 46 kgr. (92.7 lb. per yard), in lengths of 18 m. (59 ft. 5/8 in). No cant of rail. Twin rails in curves of less than 50 m. (2 1/2 chains) radius. Special steels (manganese and nickel-chrome) in curves of less than 30 m. (1 1/2 chains) radius. Flat fishplates for 8 bolts. Grover washers. Alumino-thermic welding and electric arc welding. Sleepers of untreated hard oak. Metal sleepers U. V. F., in service for last 2 years, have stood up well. Sleepers of ferro-concrete under trial for last 3 years. Rails laid direct on sleepers. Use of special manganese and nickel-chrome steels for turnouts and crossings: they give full satisfaction.

16. *Compagnie des Tramways du Loiret and connected undertakings, Paris (France).* — Length of track: 164 km. (102 miles); gauge 1 metre. Steam and petrol motor traction. Uncovered sleepers. Vignoles rails of 20 kgr. (40.3 lb. per yard) in lengths of 10 to 12 m. (32 ft. 9 3/4 in. to 39 ft. 4 1/2 in.) Cant of rails by adzing the sleepers. Half flat fishplate inside, half angle fishplate outside for 4 bolts. Grover washers. No welding. Sleepers of oak and creosoted beech. Rails laid direct on the sleeper.

17. *Nora Bergslags Railway (Sweden).* — Length of track: 12.5 km. (7.76 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignole rails of 12 kgr. (24.2 lb. per yard) in lengths of 7.50 m. (24 ft. 7 in.). Cant of rails by adzing the sleepers. Heeled angle fishplates for 4 bolts. No welding. Wooden sleepers of untreated pine. Rails laid direct on sleepers.

18. *French Est Railway.* — Length of track : 3.280 km. (2.1 miles); gauge 1.44 m. (8 ft. 8 7/8 in.). Steam traction. Vignoles rails of 30.475 kgr. (61.5 lb. per yard). Wooden sleepers.

19. *Swiss Federal Railways.* — Length of track: 218 km. (135.5 miles); gauge 1.435 m. (8 ft. 4 1/2 in.). Steam, electric and motor traction. Uncovered sleepers. Vignoles rails of 36 kgr. (72.6 lb. per yard) in lengths of 12 m. (39 ft. 4 1/2 in.). Cant of rail obtained by the shape of the soleplates. Flat fishplates for 4 bolts. Grover washers. No welding. Sleepers of oak and creosoted beech. Metal sleepers of different types give satisfaction. Soleplates.

20. *North Western Railway of Greece.* — Length of track: 74 km. (46 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignoles rails of 20 kgr. (40.3 lb. per yard) in lengths of 8 or 9 m. (26 ft. 3 in. or 29 ft. 6 3/8 in.). Cant of rail by adzing the sleepers. Flat fishplates for 4 bolts. Grover washers. No welding. Sleepers of creosoted oak. Rail laid direct on sleepers. Soleplates on curves and at joints.

21. *Compagnie générale des Chemins de fer vicinaux, Paris (France).* — Length of track : 528.680 km. (328.5 miles); gauge 1 metre. Steam traction. Uncovered sleepers. Vignoles rails of 20 kgr. (40.3 lb. per yard), in lengths of 6, 9 and 12 m. (19 ft. 8 1/4 in., 29 ft. 6 3/8 in. and 39 ft. 4 1/2 in.). Cant of rail by adzing the sleepers. Twin rails in curves of less than 40 m. (2 chains) radius. Angle fishplates for 4 bolts. Grover washers. No welding. Sleepers of creosoted oak. Rails laid direct on the sleepers.

22. *Compagnie des chemins de fer départementaux du Tarn (France).* — — Length of track : 150 km. (93.2 miles),

gauge 1 metre. Steam and petrol motor traction. Covered sleepers. Vignoles rails 20 kgr. (40.3 lb. per yard), in lengths of 12 m. (39 ft. 4 1/2 in.). Cant of rail by adzing the sleepers. Angle fishplates with 4 bolts. No welding. Sleepers of non-impregnated oak. Rails laid direct on sleepers. Soleplates at the joints and on the curves.

23. *Société nationale des Chemins de fer vicinaux (Belgium).* — Length of track : 4 511 km. (2 803 miles); gauge 1 metre. Steam and electric traction. Covered sleepers. Vignoles rails of 23 and 32 kgr. (46.4 and 64.5 lb. per yard) in lengths of 12 and 18 m. (39 ft. 4 1/2 and 59 ft. 5/8 in.). Cant of rails by adzing the sleepers. Twin rails in the curves of less than 50 m. (2 1/2 chains) radius. Barberot packing on curves of less than 75 m. (3 3/4 chains) radius. Angle fishplates for 6 bolts. Grover washers and tension plates. Aluminothermic welding and electric arc welding. Experiments with electric butt welding without fishplates. Sleepers of creosoted oak. Rails laid direct on the sleepers. Ramy plates. Soleplates on curves of less than 200 m. (10 chains) radius. Extensive experiments with crossings and turnouts of manganese and nickel-chrome steels; giving satisfaction.

24. *Rhaetian Railway, Switzerland.* — Length of track: 277 km. (172.1 miles); gauge 1 metre. Electric traction. Uncovered sleepers. Vignoles rails of 25, 27 and 30 kgr. (50.4, 54.4 and 60.5 lb. per yard) in lengths of 12 to 15 m. (39 ft. 4 1/2 in. and 49 ft. 2 1/2 in.). Cant of rails by adzing the sleepers. Chiefly angle fishplates for 4 bolts. Trials with the Lecluse bolt. No welding. Sleepers of creosoted wood. Pressed metal sleepers: give satisfaction. Soleplates.

25. *French State Railways.* — Length of track: 739 km. (459.2 miles); gauge 1 metre. Steam and petrol motor traction. On part of the line sleepers are uncovered, on the remainder they are covered. Vignoles rails and bullhead rails used. Cant of rails by adzing the sleepers for the Vignoles rails and by means of the shape of the chair for the bullhead rails. Flat fishplates with 4 bolts for Vignoles rails. Heeled fishplates for bullhead rails. Grover washers in the crossings, etc. No welding. Sleepers of creosoted oak. Vignoles rails laid direct on the sleepers. Chairs for bullhead rails.

26. *Great Western Railway (England).* — Length of track : 33.750 km. (20.97 miles) of 0.60 m. (2-foot) or 0.75 m. (2 ft. 5 1/2 in.) gauge. Steam traction. Uncovered sleepers. No cant of rail. Vignoles rails of 22.3 to 24.8 kgr. (45 to 56 lb. per yard) in lengths of 9.14 m. (30 feet). Twin rails in curves with a radius of less than 70 m. (3 1/2 chains). Flat fishplates for 4 bolts. No welding. Sleepers of creosoted pine. Soleplates.

27. *London and North Eastern Railway.* — Length of track : 232.5 km. (144.47 miles); gauge 1.435 m. (4 ft. 8 1/2 in.). Steam traction. Uncovered sleepers. Bullhead rails of 36 to 38.50 kgr. (72.5 to 77.5 lb. per yard) in lengths of 9 to 13.70 m. (29 ft. 6 in. to 45 feet). Cant of rail by the shape of the chair. Angle fishplates. No welding. Sleepers of creosoted wood. Chairs.

28. *Västergötland-Göteborg Railway, Sweden.* — Length of track: 380 km. (236.1 miles); gauge 0.90 m. (2 ft. 11 7/16 in.). Steam and petrol motor traction. Uncovered sleepers. Vignoles rails of 25 kgr. (50.4 lb. per yard) in lengths of 10 m. (32 ft. 9 3/4 in.). Cant of rail by adzing the sleepers. Angle fishplates with extended horizontal wing. Unico system of locking nut. No welding. Sleepers of untreated pine and oak.

29. *South Funen Railway, Danemark.* — Length of track: 209 km. (129.9 miles); gauge 1.435 m. (4 ft. 8 1/2 in.).

Steam and petrol motor traction. Covered sleepers inside the rails and uncovered outside. Vignoles rails of 22.3 kgr. (45 lb. per yard), in lengths of 12 m. (39 ft. 4 1/2 in.). No cant of rail. Angle fishplates with wings. Double spring washers. No welding. Sleepers of creosoted pine. Soleplates.

30. *State Railways of the Kingdom of the Serbs, Croats and Slovenes (Belgrade).* — Length of track: 2 370 km. (1 473 miles) of which 1 830 km. (1 137 miles of 0.76 m. (2 ft. 6 in.) gauge and 493 km. (306 miles) of 0.60 m. (2-foot) gauge. Steam traction. Uncovered sleepers. Vignoles rails of 19.92 to 22.1 kgr. (40.2 to 44.5 lb. per yard), in lengths of 9 to 10.83 m. (29 ft. 6 3/8 in. to 35 ft. 6 in.). Cant of rails obtained by adzing the sleepers or by the shape of the soleplates. Twin rails in curves of less than 150 m. (7 1/2 chains) radius. Flat and angle fishplates. Grover washers. Alumino-thermic welding on bridges and in tunnels. Sleepers of untreated oak and creosoted beech. Soleplates.

31. *Southern Railway (England).* — Length of track : 137.6 km. (85.5 miles; gauge 1.435 m. (4 ft. 8 1/2 in.). Steam traction. Uncovered sleepers. Bullhead rails of 34 to 38 kgr. (68.5 to 76.5 lb. per yard), in lengths of 9.64 m. (31 ft. 8 in.). Cant of rails obtained by the shape of the chair. Flat fishplates for 4 bolts. No welding. Wooden sleepers of creosoted pine. Chairs.

32. *Italian State Railways.* — Length of track: 700 km (435 miles) of 0.76, 0.95 and 1m. (2 ft. 6 in., 3 ft. 1 3/8 in. and metre gauge). Steam traction. Covered sleepers. Vignoles rails of 22.5 to 27.3 kgr. (45.3 to 55 lb. per yard) in lengths of 9 to 12.5 m. (29 ft. 6 3/8 in. to 41 feet). Cant of rails obtained by adzing the sleepers or by the shape of the soleplates. Angle fishplates. No welding. Sleepers of oak and impregnated beech (Rueping system). Soleplates.

33. *Rumanian State Railways.* — Length of track: 3 107 km. (1 931 miles). Gauge varying between 0.60 m. and 1.435 in. (2 feet and 4 ft. 8 1/2 in.). Generally steam traction Some lines are electrically equipped. Vignoles rails from 7 to 36 kgr. (14.1 to 72.6 lb. per yard) in lengths of 4 to 13 m. (13 ft. 1 1/2 in. to 42 ft. 8 in.). Cant of rails obtained by adzing the sleepers or by the shape of the soleplates. Twin rails on curves with a radius under 300 m. (15 chains). Angle fishplates with 4 bolts. No welding. Sleepers of oak and creosoted beech. Rails laid direct on the sleepers or on soleplates.

[621.132.8]

REPORT No. 1

(France)

ON THE QUESTION OF RAIL MOTOR VEHICLES (SUBJECT XX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) [1],

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Figs. 1 to 9, pp. 2208 to 2224.

Before the year 1914, attempts had been made to use internal combustion motors, similar to those used on automobiles, for branch railways but, since that time, various reasons have arisen which have greatly increased the importance of this question.

During the war, the necessity of transporting troops and supplies to points not served by the railway, or where railways could not be used on account of the proximity of the enemy, caused motor transport to become of great importance.

For this reason, the automobile industry made great strides at this period and considerable progress was realised, both as regards engine and vehicle.

Since the war, private cars, public buses and motor lorries, have increased considerably in number as a result of intensified production, and have become very serious competitors of the railway in view of their speed and the ease with which goods can be transported from door to door.

If to this is added the increased price of coal and the higher cost of labour, it will be readily understood that the competition with the railway has been sufficiently serious to urge the companies to explore any possible methods of increasing their receipts and attracting back to the railway passengers who have deserted it for the new method of transport.

The first method that occurred to them was to meet like with like and after a few necessary alterations ordinary motor vehicles were put into service on the railways.

Thus, in 1921, a Paris omnibus, fitted with suitable wheels, was put into service on the outer suburban lines, and at the same time, Mr. Tartary, who was one of the pioneers of this new method of transport, converted two ordinary motor chassis for service on the Deux-Sèvres Railway.

Since that time, developments have occurred, and if the principles of the automobile have been retained. the tendency has been, in view of the special requirements, to approach more nearly to orthodox railway rolling stock.

(1) Translated from the French.

Our report will be divided under the following headings :

1. Utility and advantages of rail cars;
2. Discussion on the various parts of rail cars;
3. Characteristics of the various types in service;
4. Financial results;
5. Conclusions.

I. — Utility and advantages of rail cars.

To attract back to the railway passengers who have deserted it, it is necessary to give them the same facilities which they have found in motor transport.

For this reason, higher speeds, more frequent services and greater comfort must be provided.

Higher speeds make it necessary to separate passenger trains from goods trains, as shunting at the stations with mixed trains exasperates the public whose desire for speed is continually increasing as a result of the demands of modern life.

A steam train, even a light one, is too costly a solution of the problem.

On the other hand, a rail car of a capacity and power strictly adapted to the traffic requirements appears able to meet the demands of the public by means of faster timing and more frequent service and with a reduced expenditure. Moreover, modern rail cars, which are generally provided with more efficient means of lighting and heating than the majority of coaches on branch lines, provide an additional attraction to the public in the form of greater comfort.

As regards the advantages to the railway, these are the following :

The engine, fuel, luggage compartment and passenger compartment being all carried on one vehicle, a very great reduction in the *weight per seat* results.

A light train for example will weigh as follows :

	In working order
One locomotive	25 tons.
One brake van	5 —
One 3rd class coach with 32 seats	6.5 —
Total . . .	36.5 tons.

which is more than 1 ton per seat provided.

On the other hand, a rail car of the Tartary type with 32 seats only weighs 2.5 tons which is 80 kgr. (176 lb.) of dead weight per seat provided.

If the light train includes a bogie coach with 50 seats weighing 10 tons, the tare weight of the train will be 40 tons, that is 800 kgr. (1 760 lb.) per seat.

The Berliet rail car with 50 seats weighing 10 tons will give a tare weight of 200 kgr. (440 lb.) per seat.

This reduction in the tare weight forms one of the principal advantages of the rail car, since the cost of a heat unit derived from petrol is about 10 times that of a heat unit produced by coal. On the other hand, the thermal efficiency of an internal combustion engine is from 2 1/2 to 3 times that of a steam engine.

From this it follows that the cost per horse-power-hour for a petrol engine is 3 or 4 times that for a steam locomotive.

Any economy therefore results from the fact that a rail car has just the required power, and that the tare weight per passenger is less than that of a steam train. It will be seen that under present day conditions, that is to say, in the absence of a fuel considerably cheaper than petrol, the rail car can only show an advantage over a steam train for transporting a small number of passengers.

As regards the permanent way, the considerable reduction in the tare weight

reduces wear on the track, in addition to which the nature of the drive avoids any hammer blow or tendency for nosing oscillations. Certain economies in permanent way upkeep may therefore be looked for.

As regards staff, the actual design of the rail car and the nature of the motor make it possible to work it with not more than two men, thus reducing cost. This advantage is not realised in every case, as a number of companies have locomotives driven by one man, the guard being able to gain access to the locomotive from his brake van.

The fact that a motor can be instantly started up, thus reducing the fulness of the fireman's day, the avoidance of loss of time through taking coal and water, cleaning the fire or sweeping the tubes, form very real advantages whereby the staff of a rail car can be almost continually employed in useful work.

Rail cars also have the advantage of being always ready in reserve without any lighting up.

Finally, we should mention an absence of smoke and of sparks which cause so many fires alongside the line.

II. — Discussion on the various parts of rail cars.

1. The capacity and type of coach work depend mainly on the class of service to be covered. This varies widely on various railways.

On some lines a frequent service is the main object, and small vehicles holding 25 to 30 passengers, such as the Saurer or de Dion rail cars, that is to say motor buses running on rails, are used. Other lines have adopted heavier vehicles with a railway type of underframe, such as the R. S. type rail car built by Messrs Renault Scemia with a capacity of 40 to 50 passengers.

2. The engines are generally designed to use petrol, benzol or a mixture of benzol and alcohol in varying proportions according to the price of these various fuels, as mentioned by the « Société des Transports en Commun de la Région Parisienne ».

Diesel or semi-Diesel engines have not up to the present been very widely used, their weight and high cost being apparently the cause, in spite of their low fuel consumption.

Messrs Renault have constructed a gas producer engine which appear to have given good results, but it is not widely used at present. The makers recommend the use of wood charcoal briquettes (carbonite) which lessens the value of this design.

The Paris, Lyons & Mediterranean Railway have used steam rail cars, but have abandoned these for petrol rail cars as a result of frequent casualties : burst water tubes and tubes made up with scale, etc...

The Algerian State Railways use steam rail cars of the Rowan type, purchased about 30 years ago, on the line from Algiers to Guyotville. They burn gas coke and are of 100 H. P.

More recently, the Algerian State Railways have purchased some petrol rail cars of the de Dion and Renault types, which seems to show that the steam rail cars have some drawbacks.

The Paris-Orleans Company has compared the various types of rail cars in a very complete report, drawing particular attention to the « *Sentinel* » rail cars of 110 to 130 H. P. Electric rail cars using nickel-iron accumulators are used by the Société des Chemins de fer Economiques des Charentes.

This method may be advantageous in the vicinity of large power stations which offer cheap current at certain hours. It has the disadvantage that the cars have to return to fixed points for recharging. Moreover, the weight of the accumulators considerably adds to the cost of traction and limits the range of action of the vehicle.

The first cost is also high. However, in France this arrangement is legally considered as an electrification of the system and the State grants a considerable subsidy, which minimises this disadvantage.

3. *Transmission.*

Internal combustion engines only work efficiently within a limited range of engine speeds, and in order to obtain speed variation it is necessary to have some form of transmission which will allow the wheels to revolve at different speeds with an almost constant engine speed.

Transmission may be purely mechanical with a gear box and cone or disc clutch as in motor cars.

Above a certain power this system is not entirely satisfactory on account of the masses of the parts concerned.

The ordinary friction clutch, which is too harsh in action, may be replaced by special devices, such as a Fieux clutch made by Messrs Schneider which forms a very ingenious solution.

Electrical transmission of the Crochat and Decauville types consist of a continuous current generator driven by the engine and motors driving the axles. This system gives a continuous range of speeds, starting is entirely free from shock, and a very easy control is obtained.

The disadvantage is the considerable dead weight and high cost.

Hydraulic and pneumatic transmissions have not been widely used, and of these it is as yet difficult to form any opinion.

4. *Change in direction of running.*

Rail cars driven from one end have the advantage that the driver is always close to his engine; the disadvantage is that the rail car can only change its direction of running at places provided with turntables or triangles unless fitted with devices for turning, such as the Saurer or Tartary types.

The rail car driven from either end is free from this disadvantage, but when running in one direction the driver cannot sense how his engine is running; the engine is not under supervision, and if an admission valve should stick causing back firing into the carburetter, a fire may extend to the vehicle or to the petrol tank with no one available to extinguish it. For this reason it seems desirable that a second employee should remain near the engine when the driver is at the other end.

5. *Springing.*

Considerable care has been devoted by French builders to the springing of the body. It has been found that simple suspension by plate springs is not sufficient, and it is necessary to have a combination of plate springs and coil springs as on tramway and railway vehicles.

Moreover, suspension of the swing link bolster type is recommended to reduce the shock when entering curves.

Finally, it appears desirable to provide an elastic connection between the engine and the frame so that the vibrations produced by the engine are not transmitted metal to metal.

Messrs de Dion use in their K. G. type rubber springs which appear to have overcome this difficulty.

In Germany the engines are mounted on a special spring suspended subframe.

III. — Characteristic features of various types of rail cars.

Descriptions of the various rail cars in service on the French railways have appeared on many occasions. The following however is given as a summary :

I. — Renault Scemia rail cars for standard gauge or metre gauge (fig. 1).

General particulars.

Four-wheel vehicles driven from either end or constructed with one driving position for running in one direction only.

There are 4 types got by using 2 engines of different powers and driving on to one or both axles.

The characteristics common to all are as follows:

Length of frame, excluding buffers: 9.70 m. (31 ft. 10 in.). Wheel base : 3.60 m. (11 ft. 9 3/4 in.).

Body. — Width 2.20 to 2.50 m. (7 ft. 2 5/8 in. to 8 ft. 2 7/16 in.).

Luggage compartment. Passenger compartment with 25 seats, one being a tip-up seat. End platform accommodating 15 passengers standing. Postal compartment.

Electric lighting.

Characteristics of the different types of frames.

TYPE.	Driving axles.	4- cylinder engine.				Approximate weight in metric (English) tons.	
		Bore.	Stroke.	Speed.	Brake.	Metre gauge	Standard gauge.
		Millimetres (inches).		Revolutions per minute.	H. P.		
R.S. 1 . .	1	100 (3 15/16)	160 (6 5/16)	1 500	45	7.4 (7.28)	7.6 (7.48)
R.S. 2 . .	2	100 (3 15/16)	160 (6 5/16)	1 500	45	7.7 (7.58)	7.9 (7.77)
R.S. 3 . .	1	125 (5)	160 (6 5/16)	1 250	58	7.5 (7.38)	7.7 (7.58)
R.S. 4 . .	2	125 (5)	160 (6 5/16)	1 250	58	7.8 (7.67)	8 (7.87)

Constructional details.

Frame. — Main frames and cross stretchers of pressed steel.

Engine. — 4 cylinders.

Carburetter with automatic air control and single jet.

Ignition by automatically advanced magneto and sparking plugs.

Forced lubrication.

Governor action on the induction.

Cooling by radiator with air fan mounted directly on fly wheel. Water circulation by thermo-syphon.

Clutch. — Inverted cone lined with ferobestos.

Gear box. — 4 speeds forward and one reverse.

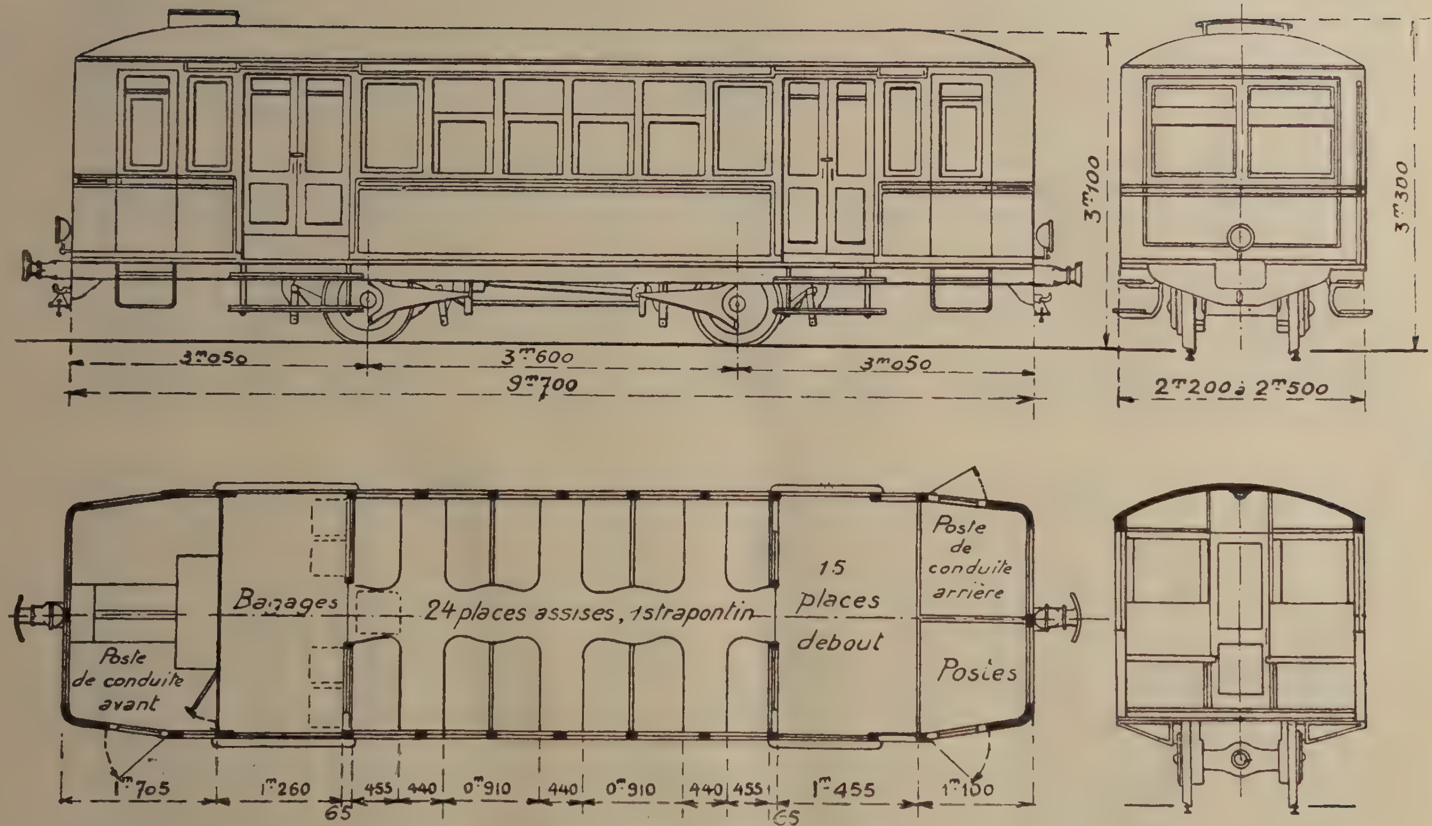


Fig. 1. — Renault Scemia (R. S.) rail car.

Explanation of French terms : Bagages = Luggage — Poste de conduite avant = Driver's compartment (front). — Poste de conduite arrière = Driver's compartment (rear). — Postes = Postal compartment. — 15 places debout = 15 passengers standing. — 24 places assises, 1 strapontin = 24 seats, 1 tip-up seat.

Normal speeds: 10, 16, 22, 40 km. (6.2, 9.9, 13.6 and 24.8 miles) per hour.

Transmission. — Cardan shaft and bevel drive.

Reverse. — The final bevel drive on the axle consists of one pinion engaging with two bevel wheels. A dog clutch sliding on the axle can engage with either of the wheels. The axle thus turns in either direction at the same speed.

Brakes. — 1. Ordinary brake internally expanding type lined with ferobestos, acting on the inside of drums mounted on the 4 wheels, operated by hand or if ordered by compressed air or vacuum;

2. Emergency brake with cast iron blocks bearing on a drum mounted on the transmission, operated by foot.

Axles and springing. — Axles running in roller bearings. Suspension by leaf springs with rubber auxiliary springs.

Controls. — Controls operated from either driving position by mechanical means.

Electric lighting and starting. — By self starter dynamo and accumulators.

Heating. — By exhaust gas from motor.

40 vehicles of this type are now in service.

II. — Renault rail car.

This company builds several types, of which we may mention the following :

1. The N. F. type for metre gauge. (Fig. 2).

General characteristics.

The N. F. type is suitable for lines with light traffic.

It can carry 30 passengers of which 24 are seated. This capacity may be increased by adding a light trailer.

The wheel base of 3.60 m. (11 ft. 9 3/4 in.) allows it to be turned on turntables of ordinary dimensions. It is driven from one end only.

The speed on the level is up to 45 km. (28 miles) per hour and direct drive can be used for all gradients not greater than 30 mm. per metre (1 in 33).

The consumption of petrol is about 25 l. per 100 km. (8.85 gallons per 100 miles).

Length of the body, 6.80 m. (22 ft. 3 7/8 in.).

Total height above rail, 3.125 m. (10 ft. 3 in.).

Distance between centre of wheels, 3.60 m. (11 ft. 9 3/4 in.).

Ordinary type of body.

End platform for 6 passengers standing. Passenger compartment with 24 seats.

Electric lighting.

Constructional details.

Underframe. — Main frames and cross stretchers pressed steel.

Engine. — 4 cylinders, 100-mm. (3 15/16-inch) bore and 160-mm. (6 5/16-inch) stroke, giving 45 H. P. at 1 500 revolutions per minute. Similar characteristics to the R. S. I type of rail car.

Clutch. — Inverted cone lined with ferobestos.

Gear box. — 4 speeds forward and one reverse. Normal speeds : 9, 14.5, 20 and 40 km. (5.6, 9.0, 12.4 and 24.9 miles) per hour.

Transmission. — By cardan shaft and bevel drive on rear axle only.

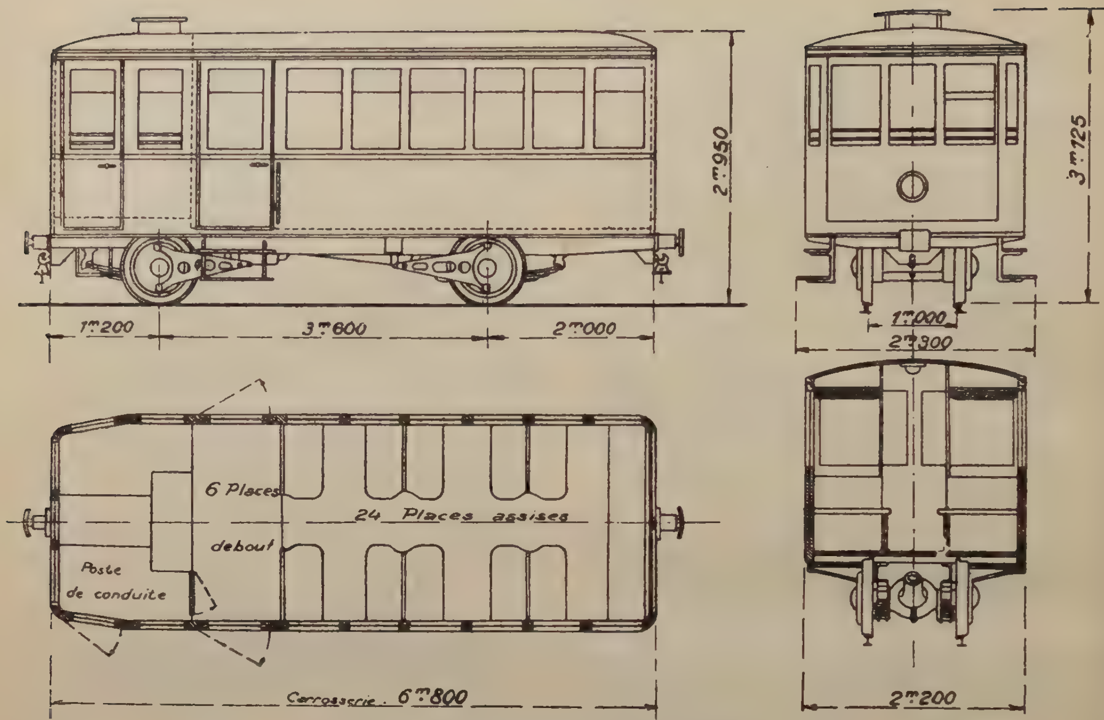


Fig. 2. — Diagram of Renault N. F. rail car.

Brakes. — Internal expanding brakes lined with ferobestos, acting on the inside of drums carried on the 4 wheels, operated by hand, and if ordered by compressed air or vacuum. A pedal allows the brakes on the rear wheels only to be operated.

Axles and springing. — Axles run in roller bearings. Suspension by laminated springs.

Lighting and starting. — By dynamo starter and accumulator.

Heating. — By exhaust gas from engine.

2 rail cars of this type are in service.

2. *Bogie rail cars.*

P. F. type for narrow gauge.
P. S. type for broad gauge.
(Fig. 3).

General particulars.

These large rail cars, carried on two bogies, are usually arranged with driving controls at each end; they can however be built with driver's compartment at one end only close to the engine.

The 4-wheel bogies are made for narrow gauge tracks of 1 m., 1.055 m. or 1.067 m. (3 ft. 3 3/8 in., 3 ft. 5 3/8 in. and 3 ft. 6 in.) (type P. F.), for standard gauge of 1.44 m. (4 ft. 8 1/2 in.) and for Russian and Spanish broad gauges (type P. S.).

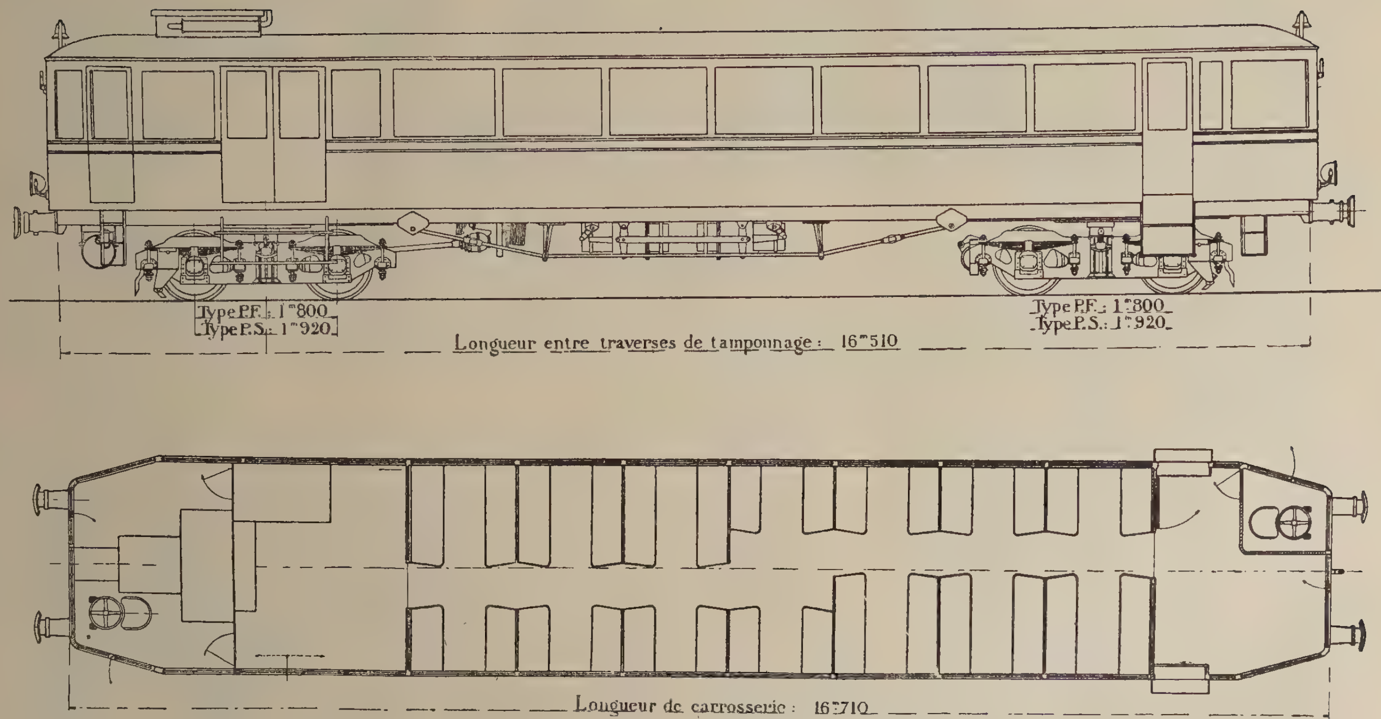


Fig. 3. — Renault rail cars, P. F. and P. S. types.

Explanation of French terms : Longueur de carrosserie = Length of body. — Longueur entre traverses de tamponnage = Length over headstocks.

The engine at one end drives on to both axles of the nearest bogie. An axle of the other bogie drives the lighting dynamo by a pulley and belt.

Length between head stocks, 16.510 m. (54 ft. 2 in.).

Distance between centres of bogies, 11 m. (36 ft. 1 in.).

Wheel base of bogies P. F., 1.80 m. (5 ft. 11 in.).

Wheel base of bogies P. S., 1.920 m. (6 ft. 4 in.).

Approximate weight of underframe P. F., 14.2 tons .

Approximate weight of underframe P. S., 15.2 tons.

Body work.

Any kind of body can be provided on these underframes such as bodies with luggage and postal compartments, seats for one or more classes, with lavatories, etc...

Constructional details.

Engine. — 6 cylinders 110×160 mm. (4 11/32 × 6 5/16 inches) developing 110 H. P. at 2 200 revolutions per minute.

Carburetter with automatic air control and single jet.

Ignition by sparking plug and magneto with automatic advance.

Forced lubrication with oil filter and cooler.

Governor acting on the induction.

Circulation of cooling water controlled by thermo-syphon.

Air for radiator circulated by fan mounted directly on the fly wheel.

Electric starting with hand starting in case of failure.

Clutch. — Inverted cone lined with ferobestos.

Speeds. — 4 speeds in each direction. Normal speeds: 10, 21, 35 and 55 km. (6.2, 13.5, 21.7 and 34.2 miles) per hour.

These speeds may be varied in accordance with the gradients to give the most suitable ratios.

Change speed operated from either driving position by one shaft having both sliding and turning motion.

Transmission. — By cardan shaft driving through reduction gearing a second cardan shaft in the opposite direction which transmits motion to the two bogie axles at the engine end.

Double reduction gear on each axle.

Reverse. — Gear reverse in gear box operated from either driving position.

Bogies. — Axles run in « Isothermos » axleboxes with oil thrower discs. Suspension by laminated and coil springs to the bogie frame connected to main frame by ball and socket joint.

No swing link bolster is provided.

Brakes. — Two independent brakes:

1. Brake blocks on all wheels operated from either end by hand wheel or by compressed air or vacuum.

2. Emergency brake on the transmission by segments and drum operated from either position by a pedal.

This brake only affects the driving wheels.

Heating. — By radiators using exhaust gas from engine.

Electric lighting. — By special dynamo mounted on the carrying bogie and driven by pulley from the inside axle.

Dynamo works with accumulator battery.

13 vehicles of this type are in service.

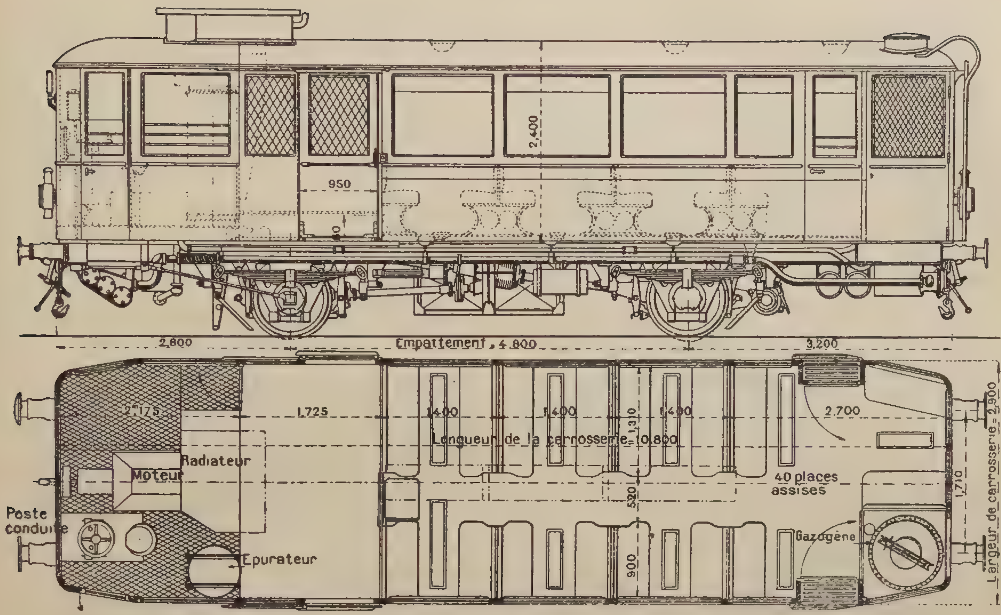


Fig. 4. — Rail car driven by 94-H. P. explosion motor fed by Renault gas producer.

Explanation of French terms : Capacité : 40 à 50 voyageurs = Capacity : 40 to 50 passengers.— Empattement : 4,800 m. = Wheel base : 15 ft. 9 in. — Epurateur = Gas separator. — Gazogène = Gas producer. — Largeur de la carrosserie : 2m900 = Width of body : 9 ft. 6 3/15 in. — Longueur de la carrosserie : 10m800 = Length of body : 35 ft. 5 3/16 in. — Moteur = Motor. Places assises = Places seated. — Poste de conduite = Driver's compartment. — Radiateur = Radiator. — Vitesse : 65 km. à l'heure = Speed : 40.4 miles per hour.

3. — *R. J. type rail car for standard gauge.* *Suction gas engine* (fig. 4).

Capacity: 50 passengers and luggage compartment.

One driving position. Speed 65 km. (40.4 miles) per hour.

Total weight: 19.7 tons loaded.

Constructional details.

Frames. — (U section) connected by pressed and rivetted cross stretchers.

Axles and suspension. — Two driving axles carried in « Isothermos » axle-boxes with oil thrower discs. Suspension by long laminated springs.

Gas producer. — Renault gas producer working on the reversed combustion principle placed at the rear of the vehicle in a closed compartment accessible from the outside. Gas purifier in the engine compartment.

The gas passes through a filter composed of a number of strainers of special fabric material.

Centrifugal hand pump for starting in the engine compartment as is also the three-way control cock.

The purified gas passes to a mixing chamber to which is also admitted the necessary air for combustion.

The producer holds enough wood charcoal for a distance of 135 km. (83.9 miles)

with trailer and 225 km. (140.4 miles) without trailer.

Engine. — 6 cylinders of 125-mm. (5-inch) bore and 160-mm. (6 5/16-inch) stroke.

Rating 94 H. P. at 2 200 revolutions per minute. Mixture of air and gas regulated by three-way cock. Starting on petrol by two automatic carburetters with atomiser to facilitate starting. Ignition by sparking plug and high tension magneto with automatic advance, adjustable by hand. Forced lubrication with centrifugal oil filter and cooling radiator.

Circulating water cooled by thermo-syphon.

Circulation of air past radiator by fan mounted on fly wheel. Starting by dynamo starter mounted on end of crank shaft connecting as a motor for starting and as a dynamo for charging accumulators.

Starting by hand from forward end of engine or from inside driving compartment as stand by.

Clutch. — Inverted cone clutch lined with ferobestos.

Speed changing. — Four speeds in either direction of running.

Normal speeds: 12, 25, 40, and 65 km. (7.5, 15.5, 24.9 and 40.4 miles) per hour.

Drive for auxiliary machinery (air compressor or vacuum pump) separate from the main transmission available when the vehicle is standing.

Transmission. — Drive by shaft to the gear box at the middle of the frame and from it by two shafts with universal joints to the two driving axles.

Reverse. — By gearing in the gear box.

Brakes. - Two independent brakes:

1. A brake on the transmission operated by pedal.

2. Brake blocks on each wheel operated by a hand wheel. The latter may also if required be operated by compressed air or vacuum.

Electric lighting. — By special dynamo suspended from underframe.

Heating. — By exhaust gases from engine.

Fuel consumption. — For rail car without trailer the consumption is 80 kgr. of charcoal for 100 km. (284 lb. per 100 miles). The hopper having a capacity of about 800 l. (28 cubic feet), contains 180 kgr. (396 lb.) of charcoal which is sufficient for a distance of 225 km. (140 miles) without trailer.

The State Railways have ordered one vehicle of this type.

De Dion-Bouton rail cars (fig. 5).

1. — *Type J. M. 3 for metre gauge.*

General arrangement. — One driving position and one direction of running.

Underframe. — Pressed steel.

Engine. — 4 cylinders 95 × 140 (3 47/64 × 5 1/2 inches) developing about 60 H. P. at 1 600 revolutions per minute.

Clutch. — Single plate, dry clutch.

Gear boxes. — Four speeds forward and one reverse.

Driving axle. — One driving axle at rear of vehicle.

Front axle. — Of motor car type with two stub axles turning on vertical swivel pins.

The stub axles are connected by a bar,

thus allowing the front wheels to freely follow curves of small radius; a spring device automatically returns these to normal position when leaving a curve and maintains them in this position when on straight line.

Suspension. — The frame is carried on the axles by four longitudinal laminated springs.

Brakes. — Each wheel is fitted with internal expanding brakes.

The brakes may be operated in three different ways as follows:

1. by hand lever with sector at disposal of driver operating on 4 wheels;

2. by pedal at disposal of driver operating on two rear wheels;

3. by hand lever inside the passenger compartment as emergency brake. Operation of the latter switches off ignition of the engine and acts on the 4 wheels.

Starting. — Electrically or by hand.

Lighting. — Electric.

Heating. — By exhaust gases.

General dimensions. — Length of vehicle without buffers, 7.63 m. (25 ft. 3/8 in.).

Wheel base, 4.35 m. (14 ft. 3 1/4 in.).

Weight empty in working order: about 6.4 tons.

Body work. — In the passenger compartment: 16 seated on fixed seats, 4 passengers seated on tip-up seats, 10 passengers standing in the corridor and about 700 or 800 kgr. of parcels or luggage in the rear luggage compartment.

Turning. — In the absence of turntables of sufficient capacity or triangles, the rail car may be fitted with a turning device which is permanently fixed to the frame and which allows the vehicle to be lifted from the track and turned end to end. This can be carried out by hand by one man in less than 7 minutes on straight level line where there is sufficient clearance for turning.

58 vehicles of this type are in service or under construction.

2. — K. G. 2. *type rail cars for metre gauge.*

General arrangement. — One driving position, one direction of running.

Frame. — Pressed steel.

Engine. — 4 cylinders 125 × 150 mm. (5 × 5 29/32 inches), developing about 80 H. P. at 1 600 revolutions per minute.

Clutch. — Dry single plate type.

Gear box. — Four speeds forward and one reverse.

Engine bed plate. — The whole of the moving parts, consisting of the engine and auxiliaries, clutch and gear box, are carried on a sub frame supported on the main frame by rubber springs to prevent transmission of the vibrations to the body.

Driving axle. — One single driving axle at the rear of the vehicle.

Leading truck. — This is of special design with a single fixed axle, the ends carrying the spring buckles.

A pivoting member with two vertical pins can turn on the axle: on the pair of pins is carried a pair of discs made of cast steel supporting at each end one of the truck wheels running free on roller and ball thrust bearings. The stub axles on either side are contrained to take the same angular displacement by means of a connecting bar.

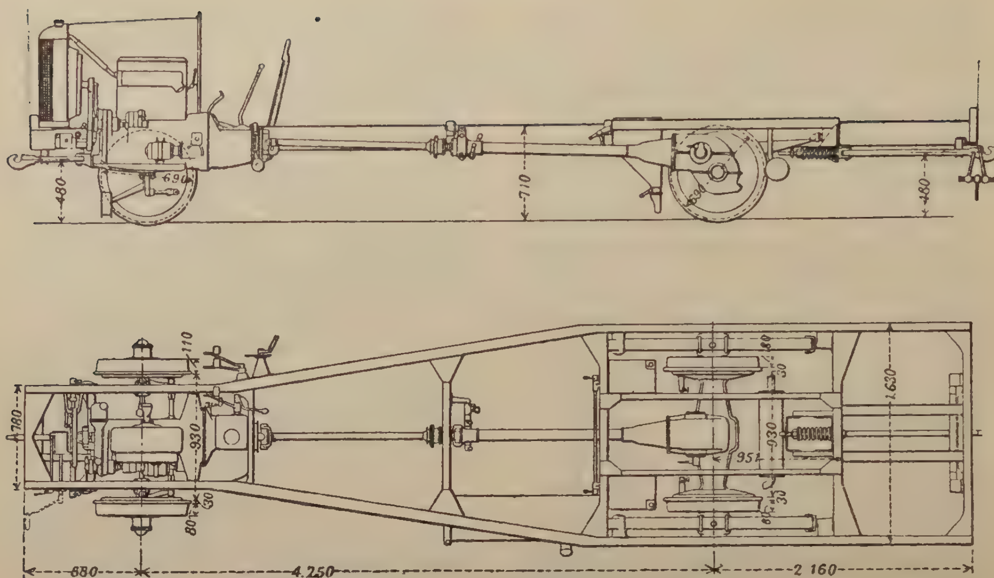


Fig. 5. — Frame of de Dion-Bouton rail car with 4-cylinder (3 47/64 × 5 1/2 inches) motor.

Springs. — The frame is supported on the axles by four longitudinal leaf springs.

Brakes. — The two leading wheels (which carry the greatest weight) and the driving wheels are each fitted with internal expanding brakes.

The brakes can be operated in three different ways:

1. By a hand lever and sector operated by the driver and connecting on all 4 wheels.

2. By a pedal operated by the driver connecting on the two rear wheels.

3. By a hand lever inside the passenger compartment, as emergency brake. The operation of this brake cuts out the ignition of the engine and acts on all 4 wheels.

Starting the engine. — Either electric or hand.

Lighting. — Electric.

Heating. — By exhaust gases.

Turning arrangement. — Similar to that for J. M. 3 type rail car.

General dimensions:

Length of vehicle without buffer, 8.885 m. (29 ft. 1 13/16 in.).

Wheel base, 4.750 m. (15 ft. 7 in.)

Weight of rail car empty in running order: about 9.3 tons.

Body. — Accommodation provided for 24 passengers seated and 16 standing, with luggage compartment.

19 vehicles of this type are in service, or under construction.

3. — *L. H. type rail car for standard gauge.*

General arrangement. — Two driving positions. Engine located nearly at the

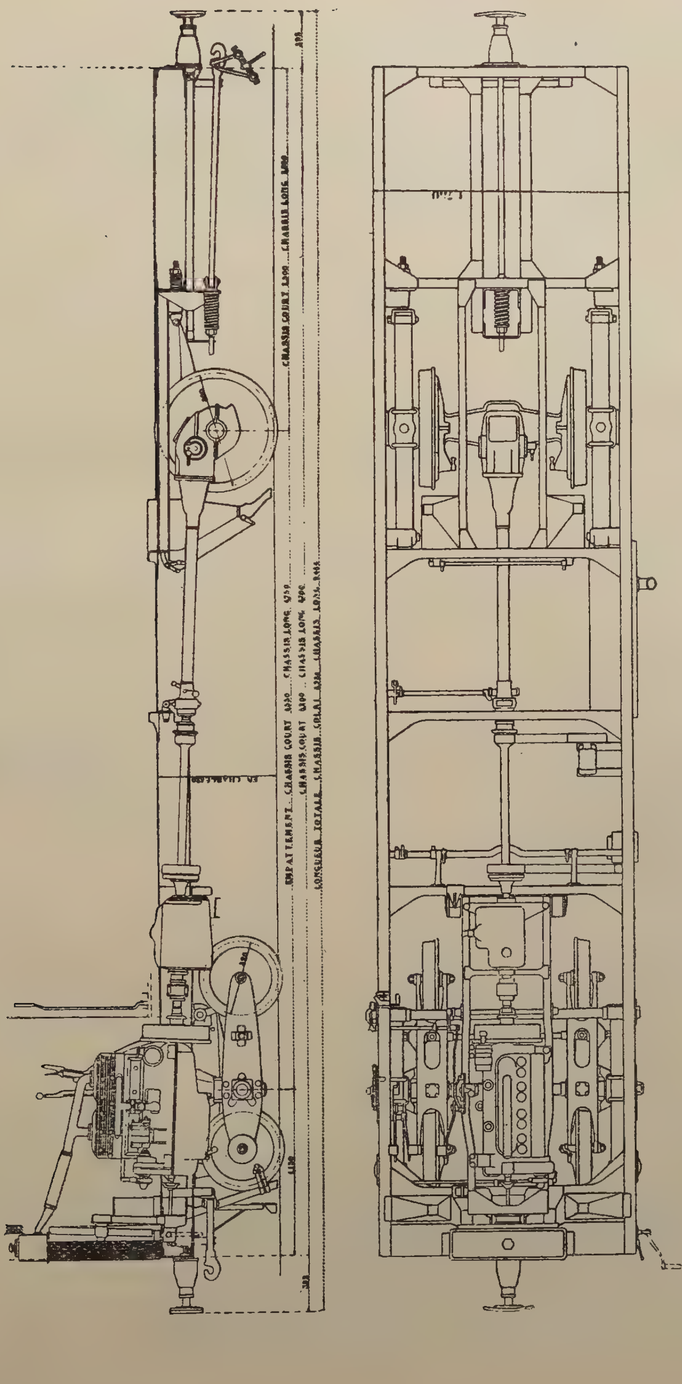


Fig. 5 (*continued*). — Frame of de Dion-Bouton rail car, J. B. type.

centre of the vehicle. The engine, with auxiliaries, and the whole of the transmission are fixed on a frame independent of the body.

Engine. — 4 cylinders, 125 × 150 mm. (5 × 5 29/32 inches), developing about 80 H. P. at 1 600 revolutions per minute.

Clutch. — Dry single plate type.

Gear box. — 4 speeds forward and one reverse (for shunting).

Driving axle. — One driving axle of the rotating type.

Carrying axle. — The second axle parallel to the driving axle is of the rotating type but does not drive.

Torque rods. — The casings of the carrying axle and driving axle are connected to the frame by torque rods provided to take the torque due to braking effect and drive.

Springs. — The frame is carried on the axles by 4 longitudinal leaf springs. The body is mounted on springs.

Brakes. — Each wheel is fitted with internal expanding brakes. The brakes may be operated in 3 ways, as follows:

1. By a hand lever and sector operated by the driver acting on all 4 wheels.

2. By a pedal operated by the driver, to control the speed, on all 4 wheels.

3. By a hand lever placed inside the body as an emergency brake and acting on all 4 wheels.

This lever is provided with a sector and cuts out engine ignition.

Bearings. — Both the driving and carrying axles run in roller bearings with ball thrust washers for lateral thrust.

Starting the engine. — Either electrically or by hand by means of a removable handle.

Reversing. — Direction of running may be reversed in about 10 seconds by operating a removable handle placed on a transverse shaft in the centre of the vehicle.

Shock absorbers. — The body is carried on the truck frame by six spiral shock absorbing springs; the 4 springs at the ends are enclosed in strong cases ensuring on effective connection between the body and the frame.

Body. — The body is entirely independent of the frame and is of the semi-metallic type; its framework is entirely of metal.

The normal arrangement provides at each end a driving compartment arranged diagonally so as to be on the left hand side in the direction of running, a luggage compartment and a postal compartment.

The remainder of the available space consists of a vestibule, wich can accommodate 20 passengers standing, and fixed or tip-up seats for 30 passengers seated.

Heating. — From the exhaust gases, when required.

Lighting. — Electric.

Schneider rail car (standard gauge). (Fig. 6).

Length 9.25 m. (30 ft. 4 3/16 in.), 2 driving axles with wheel base 3.60 m. (11 ft. 9 13/16 in.), 2 driving positions. Capacity about 42 passengers.

The engine has 4 cylinders 135 × 170 mm. (5 5/16 × 6 11/16 inches) developing 60 H. P. at 1 000 revolutions per minute.

The engine is placed towards the

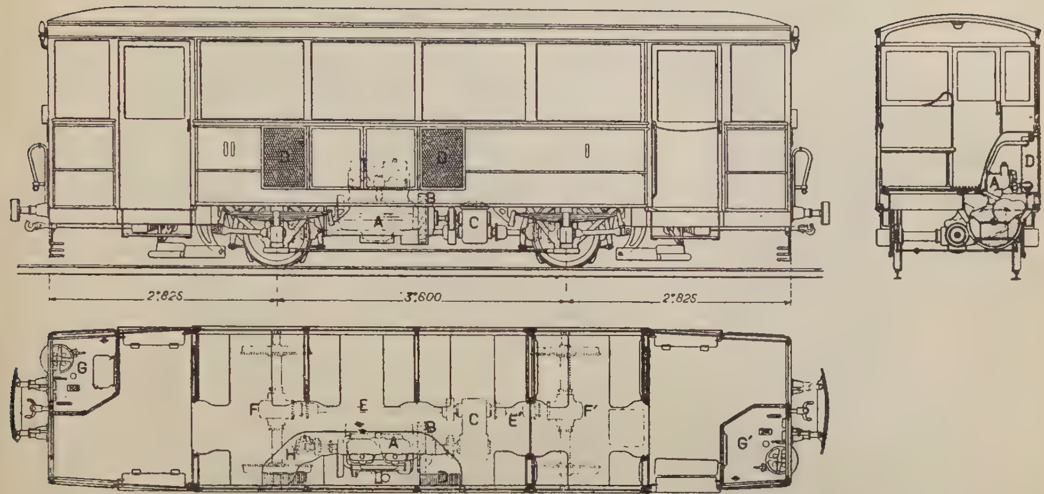
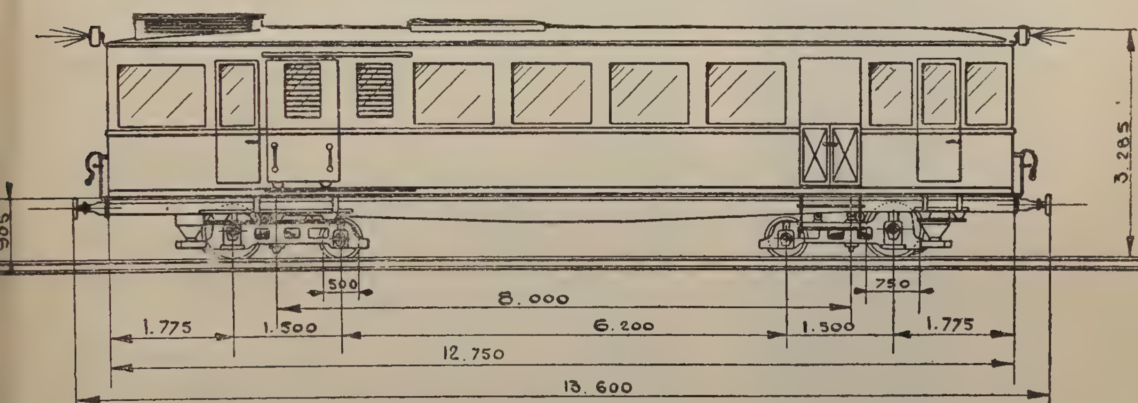
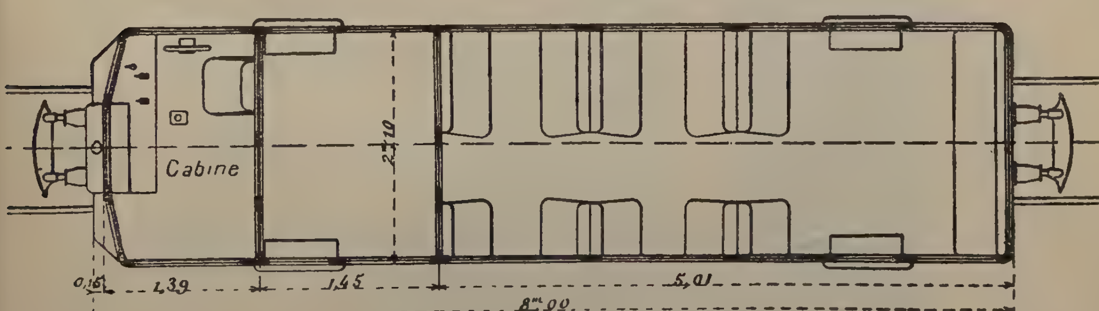


Fig. 6. — Schneider rail car for outer suburban system, Poissy to St-Germain line.

Explanation: A: motor. — B: flywheel, ventilator and Fieux clutch. — C: change speed gear. — D: radiators. — E and E′: cardans. — F and F′: = axle drive gear boxes. — G and G′: driver's compartments. — H: air compressor.



Berliet rail car, R. M. B. C. type.



Berliet rail car, R. F. M. type. — Plan of body.

Fig. 7.

centre of the vehicle to obtain a better distribution of weight.

Automatic circulation. High tension ignition. Electric lighting and self starting.

The rail car is fitted with a Fieux clutch for easy starting.

The gear box has 4 speeds and one reverse.

Two cardan shafts connect each axle with the reversing shaft.

Suspension by 4 longitudinal springs on the oil axle boxes outside the wheels.

Clasp brakes with blocks operating on the tyres.

The two driving positions are identical, with a safety locking device with one key which can only be released when the controls at one end are locked.

Weight empty: 9.8 tons.

Berliet rail car (fig. 7).

1. — *R. F. M. type rail car with 4 wheels (metre gauge).*

Length 8 m. (26 ft. 3 in.). Width 2.10 m. (6 ft. 10 5/8 in.). Wheel base 3 m. (9 ft. 10 1/8 in.).

Capacity 19 places seated, 10 standing.

One driving position.

Motor 40 H. P. with 4 cylinders, 110 × 140 mm. (4 11/32 × 5 1/2 inches).

4 speeds forward and one reverse.

The rear axle alone is driven by cardan shaft and bevel and spur wheel reduction gearing.

Two brakes: band brake on the driving shaft and brake blocks on the wheels.

Weight empty: 6 tons.

2. — *R. M. B. C. double bogie, type rail car (metre gauge).*

Length 12.75 m. (41 ft. 10 in.). Width 2.20 m. (7 ft. 2 5/8 in.). Wheel base of bogies 1.50 m. (4 ft. 11 in.).

Distance between bogie centres : 8 m. (26 ft. 3 in.).

Capacity 50 passengers. Two driving positions.

The engine has 6 cylinders 110 × 140 mm. (4 11/32 × 5 1/2 inches). 60 H. P. to 80 H. P. at 1 600 revolutions per minute.

4-speed gear box located at centre of frame.

Transmission to driving axles of the two bogies by double cardan shafts.

Vacuum brake and Westinghouse brake.

Weight empty: 9.8 tons.

Petrol electric rail cars, Decauville Company (fig. 8).

The chief feature of these vehicles is the Crochat system of electric driving gear

The generating equipment consists of an internal combustion engine directly coupled to a compound wound generator supplying current to one or two series motors according to whether the vehicles have one two driving axles.

When standing the engine turns slowly, only shunt winding of the dynamo being in use and it is connected to the motors. The shunt dynamo rotating at less than its normal speed and being connected to a series motor at rest (forming practically a short circuit), excitation is impossible.

For starting the series winding is brought into circuit the series wound dynamo being connected with a nil resistance is immediately excited, and the motor starts.

Opening the throttle increases the speed of the engine and the voltage of the dynamo and consequently the speed of the electric motors.

Speed reduction is obtained by the re-

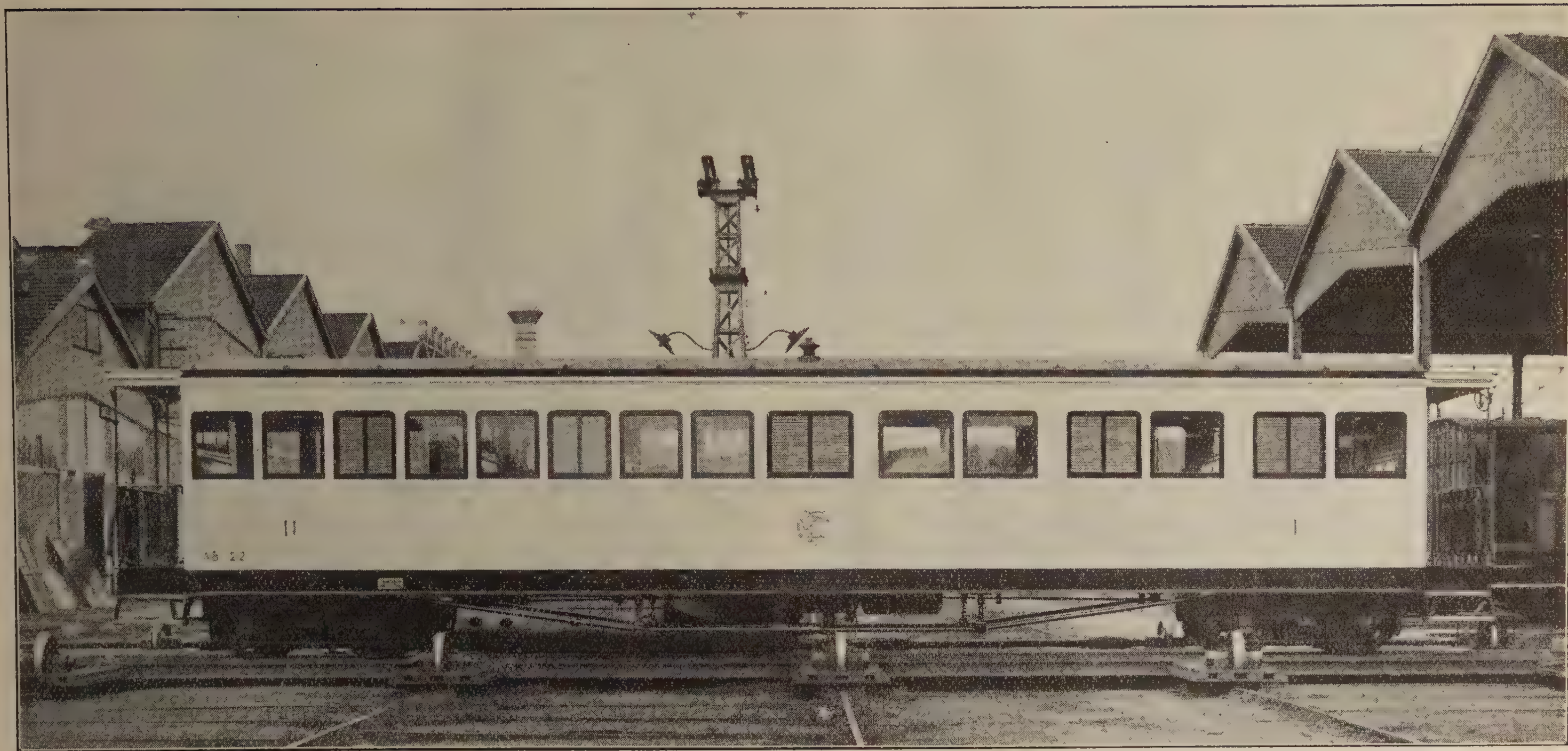


Fig. 8. — Decauville petrol-electric rail car.

verse process and stopping is effected by de-exciting the dynamo by short circuiting the series winding.

Various types of rail cars have been constructed on this system, in the first place by Messrs Crochat, and latterly by the Decauville Company after they had purchased the patent rights.

The following are the most recent:

Departmental Railways (Corsican lines), metre gauge.

2 bogie rail cars with 4 driving axles. Two 60-H. P. petrol engines, 4 cylinders, 100 × 150 mm. (3 15/16 × 5 29/32 in.).

Length of body 12.80 m. (42 feet). Distance between bogie centres : 8 m. (26 ft. 3 in.). Wheel base of bogies 1.40 m. (4 ft. 7 1/8 in.).

32 places seated, 30 standing.

2 driving positions. Hand brake and electric brake.

Weight empty: 15.7 tons.

Departmental Railways (Charentes lines), metre gauge.

1 bogie rail car. 2 driving axles. Two 30-H. P. petrol engines, 4 cylinders 90 × 150 mm. (3 17/32 × 5 29/32 in.).

Other details as the preceding one.

Weight empty : 14.8 tons.

Savoy lines.

2 bogie rail cars with 4 driving axles. One 45 H. P. engine, 4 cylinders 100 × 150 mm. (3 15/16 × 5 29/32 inches).

12 places seated, 37 standing.

Length of body 8.67 m. (28 ft. 5 9/16 in.). 1 driving position.

1 hand brake, 1 air brake. Weight 9.8 tons.

One 4-wheel rail car. One 30-H. P. engine, cylinders 90 × 150 mm. (3 1/2 × 5 29/32 inches).

Length of body 7 m. (22 ft. 11 5/8 in). 14 places seated, 16 standing.

Weight 6.4 tons.

The Calvados, Indre-et-Loire, Eure-et-Loir and Saône-et-Loire Light Railways have also rail cars of types similar to the above.

Electric accumulator rail cars. Metre gauge.

At the 4th General Technical Meeting of the Union des Voies Ferrées (Railway Union) held at Marseilles in November 1927, the Charentes Light Railways presented a very full and interesting report on accumulator electric rail cars.

The conditions to be met were as follows:

Vehicles to have two bogies, one driving and the other carrying. 32 seats and luggage compartment. Radius of action : 150 km. (93.2 miles) per hour without recharging. Speed on the level 42 km. (26 miles). The rail car should also be able to haul one or two 5-ton trailers, as all the passenger trains were to be worked by this new system.

The rail car adopted has the following characteristics:

The vehicle was built by Messrs Carel and Fouché of Mans. The electric equipment was made by the *Société Alsacienne de Constructions Mécaniques*.

The frame is very strong, since in addition to the body it carries 8.4 tons of accumulators.

It forms a container for the accumulators, being constructed as a girder of uniform strength, the cross stretchers of which form the partitions.

The 2 axles of the motor bogie are each driven by a 54-H. P. motor.

The length of the vehicle is 12.20 m. (40 feet).

The rail car is fitted with 3 brakes,

hand, direct vacuum and regenerative electric, the motors producing current when running down hill which is used for charging the accumulators.

Nickel-iron accumulators are used, these being robust and cheap to maintain. Further, the electolyte is alcaline and does not give off any corrosive gas, which allows the cells to be located in the frame.

Each battery, of the S. A. F. T. type, is composed of 180 cells (60/23), having a capacity of 750 ampere-hours for 10 hours.

The permissible rate of discharge is :

Continuous: 200 amperes;

When ascending gradients: 300 amperes for 15 minutes;

When starting: 400 amperes for 1 minute.

The accumulators are recharged by the Company at stations equipped with mercury vapour rectifiers.

Electric energy is obtained from hydro-electric power-stations as three-phase current at voltages varying from 3 000 to 13 000; static transformers reduce this to 300 volts. The current is then rectified.

Charging takes place during the night, is automatic and works without any attention.

Power is purchased at the exceptional low inclusive price of 0.16 fr. per kw.-h. The accumulators are maintained by contract.

Under trial these vehicles have shown the following cost per car-km. (per car-mile):

Electric energy . . . fr.	0.50	(0.80)
Upkeep of accumulators .	0.40	(0.64)
Upkeep of vehicles . . .	0.20	(0.32)
Upkeep of charging station	0.10	(0.16)
Wages, 2 men	0.40	(0.64)
Fr.	1.60	(2.56)

The price of this vehicle is from 300 000 to 350 000 fr.

Tartary rail cars.

The Tartary rail cars (Tramways de l'Indre and Tramways des Deux-Sèvres) have one driving position and one driving axle. Turning can be effected anywhere by means of a portable turntable.

The following are particulars of the 32-passenger type : Frame converted G. M. C. type. Length 6.45 m. (21 ft. 2 in.). Wheel base 4 m. (13 ft. 1 1/2 in.). Number of passengers: 24 seated, 8 standing. Weight empty: 2.5 tons.

In these rail cars the leading wheels can be slightly turned by the driver by means of a steering wheel to facilitate the taking of curves; the wheels are automatically brought back to normal position.

Saurer rail car (fig. 9).

This rail car is a modified motor bus and can carry 25 to 30 passengers.

The frame has straight longitudinal members of pressed steel. Wheel base 4.15 m. (13 ft. 7 inches). There are two axles, one driving and one, the leading, with spring controlled stub axles turning on swivel pins for taking curves. The leading axle may with advantage be replaced by a bogie. The engine has 4 monoblock cylinders and develops 35 to 55 H. P.

There are 4 speeds forward and one reverse.

Cast steel wheels run in ball bearings.

Saurer type power brake.

Foot brake on rear wheels.

Independent hand brake on rear wheels.

Electric equipment.

Turning by means of a turning jack fixed at the centre of gravity of the car,

Fig. 9. — Saurer rail car.

where ordinary turntables are not available.

If turntables at termini are too small in diameter, special apparatus, known as a « Sauterelle », may be used.

Weight: 5 tons.

Load: 3.5 tons.

4. — **Financial results.**

A table is given in the appendix summarising the information supplied by the various companies.

The results differ widely and it is difficult to draw any clear conclusion, for they reveal the defect inherent in all grouping together of information supplied by various administrations with their different points of view. It should be added that in this particular case the traffic conditions peculiar to each line (wages, gradients, etc.) increase still further the differences in results.

We will attempt however to deal with the question from a general point of view, assuming a daily distance of 100 km. (62 1/2 miles) on a narrow gauge system.

1. — *Staff.*

A petrol rail car requires two employees.

A steam car requires three.

If wages are reckoned at 30 fr. per day, the cost per kilometre for the steam train is 0.90 fr. and for the petrol rail car 0.60 fr. (respectively 1.44 and 0.96 fr. per mile).

2. *Fuel.*

A rail car requires 20 to 50 l. of petrol per 100 km. (7.1 to 17.7 Imp. gallons per 100 miles) according to its power. Taking the average price as 225 fr. per hectolitre (commercial petrol) the cost will be from 45 fr. to 112.50 fr. corresponding to 0.45 fr. to 1.12 fr. per km. (0.72 to 1.79 fr. per mile).

A light steam train does not burn more than 700 kgr. to the 100 km. (2 482 lb. to the 100 miles) of coal, including lighting up and standing time. Taking the average cost at 200 fr. per ton, the cost is 1.40 fr. per km. (2.24 fr. per mile).

3. — *Lubrication.*

A steam train uses about 3.5 kgr. of oil per 100 km. (12.4 lb. per 100 miles) at an average price of 3 fr. per kgr. that is to say, 0.105 fr. per km (0.168 fr. per mile).

The figures for oil consumed by rail cars vary widely for different railways from 0.5 to 3 kgr. per 100 km. (1.06 to 1.77 lb. per 100 miles).

The price of the oil used is about 7.50 fr., which gives a cost of from 0.0375 to 0.0225 fr. per km. (0.060 to 0.036 fr. per mile).

4. — *Maintenance*

The figures given by the narrow gauge systems range from 0.25 to 0.50 fr. per km. (0.40 to 0.80 fr. per mile). We have ignored the exceptionally high figures (1.15 to 2.68 fr. per km) which have been furnished by certain systems as these must include exceptional repairs.

The maintenance of a small narrow gauge train consisting of an engine, brake and one coach, may be estimated as 0.40 fr. per km. (0.64 fr. per mile).

We have therefore the following table:

CLASS OF EXPENDITURE.	Steam train.	Petrol rail car.	
		Minimum.	Maximum.
	← Francs per kilometre (per mile) →		
Staff	0.90 (1.44)	0.60 (0.96)	0.60 (0.96)
Fuel	1.40 (2.24)	0.45 (0.72)	1.12 (1.792)
Lubrication	0 105 (0.168)	0.0375 (0.060)	0.225 (0.36)
Maintenance	0.40 (0.64)	0.25 (0.40)	0.50 (0.80)
TOTAL	2.805 (4.488)	1 3375 (2.14)	2.445 (3.912)

This gives an economy ranging from 53 to 20 % in favour of the rail car.

The economy may be still greater if one takes into consideration that the rail car allows a better utilisation of the staff by reducing the time taken by the driver in shed duties before departure.

Further, the increased average speed of the rail car enables it to make a greater daily mileage, which reduces the cost of the staff per kilometre.

The addition of extra vehicles to a steam train does not increase the cost in proportion to the extra accommodation,

because the locomotive has a reserve of power, whereas the cost of a rail car increases much more rapidly with its power.

From this may be concluded that the rail car should not exceed a certain capacity without seriously reducing its economy.

5. — Conclusions.

The results of the foregoing investigation lead to the following conclusions:

Petrol rail cars appear to be suitable for a light high speed service on fairly level lines.

In the case of heavy rail cars, the advantage of the considerable reduction in the dead weight per passenger tends to disappear and the locomotive can hold its own. It may be mentioned that to start a train of 20 to 25 tons by an internal combustion engine requires special skill on the part of the driver, which accounts for failures in the transmission.

We may therefore utilise rail cars to replace existing trains where there are but few passengers to be carried and where the freight traffic necessitates a train every day. If the freight traffic only necessitates a train every two or three days, this method is apt to cause dissatisfaction among the consignors.

Attention should be drawn to the rail car as a means of providing supplementary trains to bring back passengers who have deserted the railway owing to the infrequency of the service. It should be noted that to satisfy the public it is essential that the line should pass at close proximity to the towns and villages, as otherwise the motor bus which passes right through them will continue to attract former users of the railway.

The advantages which have been found are as follows:

A lower cost per kilometre;

Higher average speed;

No need for spare engines in steam with a corresponding saving in staff;

Immediate starting up of the spare rail car;

Reduction of standing time for heavy repairs, when spare engines are kept and where the engine is easily removed;

Greater cleanliness due to the absence of smoke;

Greater comfort for the passengers, if special provision is made for damping out engine vibrations.

The disadvantage is the high first cost of rail cars which leads to a high rate of depreciation. It is difficult to give any figures for this depreciation as the relatively short time since they were put into service does not allow any exact figures to be given as regards their life.

It is to be hoped that the price may be reduced by mass construction, which does not appear likely to take place in the near future, as builders are giving more attention to the construction of motor buses, which at the time are enjoying a boom. This however will tend to disappear as soon as the State and the local authorities fully realise the burden of the resulting cost of road maintenance.

Finally. when the use of a cheaper fuel than petrol has been perfected, rail cars, even of the larger type, will be able to provide a profitable service.

To conclude it may be stated that:

Wherever traffic conditions have allowed rail cars to be substituted for steam trains, experience has shown that the change has shown a financial saving, which will become greater when tests with new forms of fuel or with other sources of energy, such as electric accumulators, have confirmed the results which have already been obtained.

APPENDIX

TABLE I.

Information supplied by Railways.

RAILWAY.	Type of rail car.	Horse-power.	Weight, metric (English) tons.	Consumption per 100 km. (per 100 miles). Petrol. Litres (Brit. gallons).	Consumption per 100 km. (per 100 miles). Oil. Kgr. (lb.)	Total expenditure per km. (per mile) Francs.	Expenditure for steam train. per km. (per mile). Francs.
1. NARROW GAUGE.							
Deux-Sèvres Tramways	Tartary	18	3 (2.9)	25 (8.9)	1 (3.54)	1.27 (2.04)	7.317 (11.77)
Indre Tramways	Tartary	18	3 (2.9)	20 (7.1)	0.75 (2.66)	1.30 (2.09)	5.44 (8.75)
Algerian State Railways. . . .	de Dion	25	5 (4.9)	35 (12.4)	—	6.05 (9.73)	11.10 (17.86)
Departmental Railways	Decauville	30	8.5 (8.4)	28 (9.9)	0.8 (2.83)	1.46 (2.34)	2.75 (4.42)
Indre Tramways	de Dion	40	5 5 (5.4)	25 (8.9)	0.75 (2.66)	1.30 (2.09)	5.44 (8.75)
Tarn Departmental Railways . .	R. S. 1	45	10.3 (10.1)	33 (11.7)	0.5 (1.77)	2.26 (3.63)	3.20 (5.15)
Compagnie Générale de Voies Ferrées d'intérêt local	de Dion	45	9.3 (9.1)	28 (9.9)	0.75 (2.66)	1.83 (2,94)	"
do.	de Dion	45	10 (9.8)	28 (9.9)	0.75 (2.66)	2.15 (3.63)	"
Departmental Railways	R. S. 1	45	10.5 (10.3)	46 (16.3)	4.9 (17.4)	2.44 (3.92)	3.71 (5.97)
do.	de Dion	50	5.8 (5.7)	28 (9.9)	0.5 (1.77)	1.10 (1.77)	2.75 (4.42)
do.	Saurer	55	6 (5.9)	28 (9.9)	2.1 (7.4)	1.58 (2.54)	2.33 (3.75)
Tarn Departmental Railways . .	R. S. 4	58	11.4 (11.2)	55 (19.5)	1.5 (5.3)	"	3.20 (5.15)
Secondaires Nord-Est	R. S. 4	58	7.8 (7,7)	65 (23.0)	4.4 (15.6)	2.75 (4.42)	4.50 (7.24)
Paris, Lyons & Mediterranean Railway (Algerian Lines) . .	Berliet	60	12 (11.8)	53 (18.8)	2.8 (9.9)	3.54 (5.69)	10.20 (16.41)
Indre Tramways	de Dion K.G.	60/80	10 (9.8)	35 (12.4)	0.75 (2.66)	1.30 (2.09)	5.44 (8.75)
Paris-Orleans Railway	Renault	60	13 (12.8)	32 (11.3)	1.2 (4.25)	1.40 (2.25)	3.10 (4.99)
Tunisian Railways	Y. Z. L.	80	25 (24.6)	52 (18.4)	2.9 (10.3)	"	11.45 (18.42)
Algerian State Railways. . . .	Renault	85/100	22.8 (22.3)	65 (23.0)	3 (10.6)	7.0 (11.26)	11.10 (17.86)
Departmental Railways	Decauville	100	16 (15.7)	50 (17.7)	3.3 (11.7)	1.85 (2.97)	3.55 (5.71)
do.	do.	120	18 (17.7)	80 (28.3)	7.8 (27.7)	3.15 (5.07)	3.91 (6.29)
Algerian State Railways. . . .	Rowan (steam)	100	9.1 (9.0)	coke 435 kg (1532 lb.)	"	2.19 (3.52)	11.10 (27.86)
2. STANDARD GAUGE.							
Transports en commun de la Région Parisienne.	R. S. 4	60	10.7 (10.5)	34 (12.0)	2 (7.1)	"	"
French State Railways	Converted vehicle	85	14.5 (14.3)	64 (22.7)	3 (10.6)	2.31 (3.71)	3.32 (5.54)
Paris-Orleans Company	Sentinel (steam)	70	26 (25.6)	Coal 280 kg. (990 lb.)	2.8 (9.9)	2.48 (3.99)	4.10 (6.60)
French Nord Company	(Steam)	255	"	Coal 775 kg. (2730 lb.)	2.1 (7.5)	4.50 (7.24)	8.40 (13.52)

[621 .132.8]

REPORT No. 2

(all countries except Europe)

ON THE QUESTION OF RAIL MOTOR VEHICLES (SUBJECT XX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION),

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Figs. 1 to 4, pp. 2239 to 2242.

SUMMARY.

1. There is now recognition of the necessity for a light weight rail motor car on practically all the steam railways of the world.

2. A large proportion of the total utilize the internal combustion engine as the prime mover, and except for cars of less than 150-H. P. rating, use electrical transmission.

3. There is a strong tendency in America to develop high speed rail cars of from 300 to 400-H. P. rating, operating as a train of 150 tons and capable of doing 65 miles per hour.

4. The requirements of heavy equipment of this class can best be satisfied by the use of the oil engine of the high pressure, airless injection, light weight type.

5. The advantages of the oil engine over steam or gasoline are its higher thermal efficiency, the lower cost of fuel and its absence from fire hazard. For a given number of heat units in the fuel, available at the wheel rim, the fuel costs are in the following proportion :

Oil : 15; coal : 39; gasoline : 97.

6. The analysis of the operation of the 300-H. P. cars on the Canadian National Railways for twelve months, 1927-1928, shows a net revenue, after interest and depreciation have been deducted, of 52.8 ct. per motor car mile.

7. Perhaps the most economical application of the oil electric equipment is in terminal switching service, where it shows an overall efficiency of 21 % as compared with an average of 2.26 for steam. This fact represents a saving in fuel alone of $ 8 000 a year, or 9 % on the total capital cost.

8. The arguments in favor of electrification so well marshalled by its protagonists, apply equally well, within the capacity of the prime mover, to the oil-electric locomotive — flexibility of control, high rate of acceleration, possibility of multiple unit operation; — all without the high charges for the generation and distribution of power.

9. The number of applications of the oil engine to transport problems is continually increasing. It is now being tried on steam railways, in highway

buses and trucks, and in air craft. The proper dissemination of the knowledge gained by this varied experience will be welcomed by all engineers who are engaged in its development.

Rail motor vehicles.

As far back as the beginning of the present century, it was recognized by railway engineers that there existed an opportunity for a light-weight and economic type of motor rail car for certain classes of railway traffic. This was met to some degree in England by the steam unit rail coach and in the United States by the gasoline car. In Sweden as early as 1913, the first of the Diesel cars was put in service on the Swedish State Railways.

Although considerable work was done on the design of this equipment, it was only after the war that the necessity for lower operating costs gave it its great stimulus. It was felt that the unit rail car would at once require less for capital expenditure for equipment, afford a more economical use of fuel and probably reduce the total cost of the labor of operation.

As a naturel result of the ever increasing use of the gasoline engine in the automobile and highway truck, an effort was made to use a standard road bus by substituting flanged car wheels and making the front axle rigid. But this car, with a capacity of not more than twenty passengers, had a limited field and soon proved very high in maintenance, due to its inability to withstand the rail shocks which are much more severe than those experienced in highway service, where the rubber tires act as shock absorbers.

The next step was the general use of a light-weight rail car having two 4-wheel trucks on, or over, the front of which was mounted a gasoline engine of about 100 H. P., connected through clutch and gears to one axle of the front truck. Usually three speeds forward and two or three reverse were provided. These cars had a seating capacity of about 50 passengers and weighed about 80 000 pounds.

Larger cars having a 250-H. P. engine and a total weight of 120 000 pounds have been tried but there is now a strong opinion on the American continent that when cars are equipped with engines of over 150 H. P., the difficulty of changing gears and the cost of maintaining the mechanical transmission justifies the use of electrical transmission.

In 1917, the railways in Canada put in service a number of storage battery cars driven by four 25-H. P., 250-volt motors, with battery capacity to give an operating range of about 110 miles per charge on normal gradients. This type of equipment had the advantage of having the complete floor space within the car available for passengers and baggage, as the battery was carried beneath the floor in suitable boxes mounted between the trucks. The car proved expensive in first cost, however, and was limited in its field of usefulness on account of the length of run which it could make on one charge, and also by the necessity of providing charging equipment, usually at both ends of the run, as well as by the time involved for charging the batteries. The operating characteristics were very satisfactory but the operation was economical only when power was cheap, as the overall efficiency of the battery and motors is about 50 %. The cars weighed 70 000 pounds and operated at a power output of 40 watt-hours per ton-mile. This figure was an average of several different runs and was obtained by measurement of the battery output.

In England, during this same period, several manufacturers developed a steam rail car which was the outcome of the steam lorry as used on the British highways. In the first of these a horizontal engine was connected to a jack shaft which, in turn, was connected by chain to the driving axle. In the next type a vertical engine was used capable of developing about 100 H. P. The present steam car is fitted with a 6-cylinder horizontal engine, single acting, designed to work with steam at 300 pounds per square inch and a temperature of 700° F. The boiler has a capacity of about 2 350 pounds of steam per hour. The engine power is transmitted to a gear box mounted on the front axle of the front truck by means of a cardan shaft, fitted with universal joints and splines to take care of the relative motion between the truck axle and the engine. The engine will develop about 130 brake horse power at 500 revolutions. The car will carry about 3 360 pounds of coal, which is sufficient for a 300-mile run, also 315 gallons of water which is sufficient for an average run of 60 miles. It has double end control, will seat 56 passengers, weighs 72 000 pounds and has a maximum speed of 55 miles per hour, with an engine speed of 750 revolutions per minute.

This car has been developed to meet the light traffic conditions on the British railways and is used, as will be noted in the summary at the end of this paper, very largely throughout the British colonial railways. In the recent technical press, mention is made that a steam car similar to the above has been introduced on one of the mountain railways of Spain, operating satisfactorily on a 2 % grade at not less than 20 miles per hour.

Although there is now and probably always will be, a field for the small mechanical power on the railways of Canada and the United States, the great demand here is for a high speed car with a power plant of 300 H. P. or more and capable of pulling two or more trailers, making a total train weight of from 150 to 200 tons.

This class of service requires a train consisting of a motor car about 73 feet long with a power plant of from 300 to 400 H. P. installed at one end and with the balance divided into baggage and mail compartments or possibly for baggage and passengers, together with 65-foot trailers weighing 60 000 pounds and each seating about 60 passengers. These trains must be capable of maintening a schedule speed of 33 miles per hour with 5 miles between stops and of attaining a maximun speed of 65 miles per hour.

It will be noted that the unit rail car is becoming nothing more or less than a locomotive, and, in fact, when equipped with more than say 400 H. P. in engine, it is a question whether it should not be built as a power unit only, and used to draw any type of coach equipment up to the limit of its capacity. It would seem that there is only one way to interpret this tendency, and that is, that the railways of America recognize the internal combustion engine as a permanent type of railway motive power, and are constantly trying to increase its field of usefulness. It is the author's opinion that this is so, and that the internal combustion locomotive offers many advantages over the standard type of steam engine.

From the data at hand, which although not complete, may be considered representative, there are on the railways under consideration, at least 1 214 unit rail cars divided into types and sizes as follows :

TABLE I.

—	150 H. P. or less.		Between 150 H. P. and 300 H. P.		Above 300 H. P.	
	Mechanical drive.	Electric drive.	Mechanical drive.	Electric drive.	Mechanical drive.	Electric drive.
Steam.	83	...	...	...	...	...
Battery	5	...	...	...	..	...
Gasoline. . . .	413	12	148	324	...	150
Distillate . . .	...	...	...	43	...	16
Diesel.	...	...	...	18	...	2

From the above it is seen that for the low power class with either steam or gasoline, the mechanical drive is almost universal. There always will be a field for a low cost type of mechanical car, which is easy to operate and cheap to maintain.

In the intermediate class, the mechanical transmission shares the honors with the electrical drive, whilst in the heavy class the drive is almost entirely electrical.

The reasons for the above are that in small cars with mechanical transmission and speed change gears, the cost is low, the operation is easy and the transmission is light, therefore the track shocks are not excessive, and the maintenance is reasonable. In the heavy cars, or trains with large power, however, the very opposite is true. And, besides this, the schedules are usually such that full engine power is required continuously throughout the accelerating period, which can only be obtained by means of the uniform gradations of electrical control.

Representing present day developments in heavy rail cars equipped with internal combustion engines, there are three classes depending upon the type of fuel used, namely :

a) Gasoline,

b) Distillate,

c) Fuel oil (Diesel).

These classes will be touched on separately, emphasizing what are considered the chief points of each and an effort will be made to compare their operating results. In this as in all other comparisons that follow, the Imperial gallon and short ton (2 000 lb.) are used, and costs are based on current prices in Canada, unless otherwise specified.

a) Perhaps the chief factors in favor of the gasoline engine in rail car service are its general use in automobiles and buses, resulting in a familiarity with, and knowledge of its operation, on the part of most mechanics, the great number in which gasoline engines are manufactured, giving a low production cost; and the universal distribution of the fuel throughout the country. It is highly dependable in service and, coupled with electrical transmission, lends itself to very satisfactory operation.

The chief disadvantages are the ex-

plosive property of gasoline, forming a serious hazard to the life of passengers and safety of property; the high cost of fuel; and the relatively low thermal efficiency of the gasoline engine, say 21 % for the engine or 17 % from the fuel to the wheel rim, including the electrical transmission. An inherent fault in this class of engine is crankcase dilution. Particularly during idling periods and before the engine has been heated, a certain amount of the heavier portions of gasoline passes the piston rings and mixes with the lubricating oil. The temperature in the crankcase is usually high enough to vaporize these oils and to keep the accumulation from exceeding about 15 %. But even the presence of this amount frequently causes crankcase explosion, if the pistons are not in the best condition. This fact in itself on some runs makes it necessary to change the lubricating oil after every 1 500 miles.

b) By distillate is meant an oil resembling kerosene, a suitable specification being as follows:

Specific gravity . . 0.84 or 36° Beaumé.
Viscosity Saybolt
Universal . . . . 34 secs. at 100° F.
Heat value . . . . 18 700 B.T.U. per lb.

Distillation range:

Initial	362° F.
20 % over at	421° »
50 % »	448° »
90 % »	526° »
95 % »	576° »
End point	614° »

Sulphur content: 0.3 % maximum.

From this specification it is seen that distillate is a volatile fuel between gasoline and light fuel oil. Its application has not become general on the American continent, as it would appear that it is derived only from certain crudes. At the present time, June 1929, the only satisfied users in rail motor cars are those who secure the oil from the western and southwestern oil fields in the United States.

The oil is burned in a modified gasoline engine fitted with special carburators, one for each cylinder, and an abundant ignition system of duplicate magnetos and four spark plugs per cylinder. The oil is not vaporized before admission but is carefully measured and mixed with air in a fixed ratio, by means of a rotary air throttle and multiple fuel jets which form part of the carburator. The carburators must be nicely adjusted and the ignition nicely timed, to guarantee accurate firing and complete combustion. Gazoline is used for starting and until a suitable running temperature is attained.

The chief advantages are reduction of the fire hazard, due to the smaller quantity of gasoline carried, and to the lower inflammability of the fuel itself; the reduction in the cost of fuel, where suitable oil can be obtained; the reduction in the carbon monoxide content in the exhaust; and the ability to use the gasoline engine with modifications, with its lower first cost as compared with the oil engine.

The disadvantages are the perpetuation of the two chief causes of trouble in the gasoline engine, carburation and ignition. Crankcase dilution is also a serious difficulty and is such as to make it necessary to change and filter the lubricating oil every 300 or 400 miles. There is a reduction from 3 % to 5 % in power developed when using distillate, as compared with gasoline. The distillate burning engine cannot be considered as a general type, or at least as being satisfactory as such. In Montreal, for ex-

ample, a fuel resembling the specification as given above, can only be purchased at a price equal to that of gasoline, which at once offsets its economic advantages.

c) The data on the use of oil engines in motor rail cars herein presented are particularly based upon the experience which the authors have gained upon the Canadian National Railways, which have been operating this type of car for nearly four years, having fourteen in service with seven under construction. With the experience of about 2 000 000 motor car miles, the original venture has been justified and the permanency of the type is assured.

The name « Diesel » is popularly applied in America to the oil engine as designating one which fires from the temperature of compression and not from an external source of ignition. It is not used in the European sense, that the engine conforms to the original Diesel constant pressure cycle.

The engines used on the Canadian National Railways are of the airless injection type and do not conform to the constant pressure cycle. « High Pressure, Airless Injection Type » would probably be a more satisfactory name.

The semi-Diesel engine is one in which the temperature of compression is not sufficiently high to ignite the fuel, making it necessary to employ an auxiliary heat supply such as a hot plate or bulb.

The advantages of the oil engine are its absence from fire hazard; its ability to burn a low price fuel, easily obtainable anywhere; and its high thermal efficiency.

The first two criticisms to be heard against the oil engine are its high first cost and the degree of mechanical skill required for its maintenance. The first of these is true as compared with the cost of equivalent power in steam or gasoline engines, but this is not a condition which is necessarily permanent. On the contrary, with the advancement of the art and with the increase in the quantity of production, the first cost will become comparable with that of the gasoline engine. And, until then, is it not a question of the balance between the savings in operation and the interest on the difference in capital costs?

The following comparisons in fuel costs are of value in showing the savings in this one item alone, which are available for paying the interest charge on additional capital expenditure.

TABLE II.

—	B. T. U. per pound.	Weight, lb. per gallon.	Price on locomotive or car.	Overall efficiency to wheel rim.	Cost per 100 000 B. T. U. at the wheel rim.
Coal (mechanical) . .	12 900	...	$ 5 per ton	5 %	39 cents.
Gasoline (electric) . .	18 300	7.30	22 cents per gallon	17 %	97 —
Fuel oil (electric) . .	19 000	8.65	6.5 cents per gallon	26 %	15 —
Distillate (electric) . .	18 700	8.20	22 cents per gallon	16 %	90 —

Expressing this in another form, the annual cost of fuel based on the consumption of a 300-H. P. motor rail car as taken from Canadian National Railways' records for 1928, would be:

Oil	$ 1 445.00
Coal	$ 3 757.00
Gasoline . . .	$ 9 344.00
Distillate . . .	$ 8 670.00

The second criticism must not be accepted without first having given it very careful consideration. A railway which has adopted the oil engine as a type of motive power should at once recognize that it has entered into a new field which requires a different knowledge and treatment than that made standard by the steam locomotive. The complexities or delicacies of the engine, if they exist, are matters of manufacture rather than of maintenance and it is not necessary for the mechanics to possess any greater degree of mechanical skill than is possessed by first class machinists in railway shops. Even this skill comes into play only during machining operations as a part of general repairs, and is not a part of the ordinary maintenance operations required in making running repairs.

One of the first steps to be taken by a railway, as has been done effectively in several of the countries of Europe, is to recognize the necessity for special training, and to make some department responsible for the education of the mechanics and drivers maintaining and operating the internal combustion engine equipment. The employees interested should be formed into classes and given a course of instruction in the fundamentals of the construction and functions of the various parts of the equipment; in the theory of the engine cycle, the adjustment and timing of the valves, etc.; and in the theory of direct current as applied in the generator, motors and storage battery. This course of instruction can be greatly simplified by the use of large scale typical or schematic drawings, and by the use of models.

At first glance this may seem to be a large undertaking and to be one in which the management will not receive the support of the employees. To the contrary, however, experience has shown that the mechanics and locomotive drivers connected with the maintenance and operation of oil engines soon become interested in their work and are anxious to improve their knowledge of the equipment, which they too realize is going to play an ever increasing part on steam railways. A school of instruction, as suggested, would undoubtedly receive their strong support in a short time after its inception. There is no question that much educational work must be done if a railway is going to enter into this new field, and the expenditures involved will surely be justified by an improved operating efficiency.

At the present time, the drivers of oil-electric cars on the steam railways of the United States and Canada, are recruited from the regular locomotive drivers and are, therefore, qualified in the train operating rules. They do receive, however, special instructions on the internal combustion engine and electrical equipment. The point to be emphasized is that railway officers must recognize the oil-electric locomotive or car as new and special equipment and not require it to conform to all the maintenance standards of steam equipment.

It is the authors' opinion that rail cars and locomotives requiring anything above 250 H. P. will prove most satisfactory if equipped with oil engines of the high pressure, airless injection type. These engines should be 6 cylinder, four stroke

cycle, running between 800 and 1 000 revolutions per minute and should weigh from 15 to 20 pounds per brake horse power. The engine should be rigidly coupled to a direct current generator without an intermediate generator bearing, thereby saving in overall length. The generator should have ample capacity to deliver full engine torque at low voltage and without excessive heating, in order to operate satisfactorily on long heavy grades. The traction motors should be of proportionate capacity and connected for three running speeds namely, series, parallel and shunt field. Very satisfactory engine starting can be obtained from a storage battery driving the main generator as a motor, the battery also providing train lighting, initial excitation of the exciter, and power for operating the air compressor if the engine is not running. The idling speed of the engine should be as low as possible in order to reduce the noise of the engine to the minimum while standing at a station and the governor should be such as to prevent hunting at this speed. Except at full speed, the governor regulation between no load and full load need not be very close. In fact, it is questionable whether the hand throttle is not sufficient between idling and full speed. An overspeed trip should be provided. Present equipment is operating at a normal speed of 800 revolutions which idles very satisfactorily at 300 revolutions. The electrical equipment should be designed so that the air system and storage battery may be fully charged while running at the idling speed. The crankshaft should be fully counterbalanced and also fitted with a vibration damper. When operating at speeds varying from 300 to 800 revolutions, it is practically impossible to keep from passing through periods of critical shaft vibration. By means of the vibration damper and also with the electrical control so arranged that the engine cannot remain in a critical speed, satisfactory operation can and is being secured.

The performance of such equipment may be indicated by the summary of the data of the five 300-H. P. cars on the Canadian National Railways for twelve months 1927-1928, as follows :

TABLE III.

—	*Operation.*	—
1	Motor car miles	294 335
2	Average miles per day	302
3	Trailer miles	389 388
4	1 000 ton miles	41 243
5	Failures in service	26
6	Moto car miles per failure.	11 330
7	Moto car miles per gallon fuel	3.12
8	Gallons per 1 000 ton miles	2.67
9	Per cent lubricating oil to fuel	10

TABLE III. (*Continued.*)

—	*Unit costs.*	—
10	Supervision per motor car mile	1.5 cents.
11	Wages — —	14.4 —
12	Fuel — —	3.4 —
13	Lubricating oil — —	2.9 —
14	Repairs — —	16.1 —
15	Other supplies — —	3 0 —
16	Total — —	41.3 cents.
17	Depreciation — — . . . . (Engine 6 %, other equipement 4 %).	1.3 —
18	Interest at 5 %	1.4 —
	Total with depreciation and interest	44.0 cents.
19	Net revenue per motor car mile	52.8 —

As can be seen from this data the lubricating oil consumption is higher than it should be partly from excessive loss on the piston liners, and partly by its pollution from the accumulation of carbon. The first of these causes must be given further study by the manufacturers, but it is fully believed that by the proper treatment of the cylinder liners, and the disposition and selection of the piston rings, the losses from this cause will be greatly reduced. The second cause can be materially lessened by the use of suitable filters, operating continuously on the lubricating oil supply. The ideal condition, of course, would be one in which the filter was directly connected into the lubricating oil circuit so that all oil entering the engine would pass through it. To do this, however, requires too large a filter. The next best scheme is to install a motor driven centrifuge operating continuously and connected so that oil is drained from the bottom of the lubricating oil tank and delivered back into the top. It is felt that by this means the carbon content (Conradson test) can be maintained not to exceed 3 %, which will add appreciably to the life of the oil. A ratio of lubricating oil to fuel oil of 3 % is generally considered reasonable at the present time, but there is no reason why this should not be improved as a result of more concentrated research.

Another item which is too high is that of repairs. In the figures as presented there infortunately is considerable labor which is not a normal charge but consists in charges made on account of changes in design. There is no doubt that with a proper maintenance organization and facilities, this item can be kept down to eight cents per mile.

For railway service, the oil engine should be as light per horsepower as can be obtained without sacrificing reliability. By means of high cylinder pres-

sures, high shaft speeds and the proper selection of materials very reasonable weights can be obtained. Departure from previous standards in these respects has produced new problem of design, but it is firmly believed that by the use of the most modern methods of manufacture in securing true and extremely hard wearing surfaces, the very desirable feature of light weight per horsepower can be secured with perfect dependability. Progress in engineering has largely been the result of the engineer exceeding standard practices, and then demanding new materials or processes from the metallurgist to satisfy the conditions which he made.

One of the most important points in connection with the operation of motor rail cars is to keep them in service and at a reasonable cost for repairs. It has been found by many railways operating gasoline engine equipment and also by transport companies operating highway buses and trucks that a guarantee against failure is secured by anticipating excessive wear. In other words, by establishing a replacement schedule of all the vital parts, and putting the car through a complete overhaul at fixed times, the highest degree of maintenance is secured. The difficulty in this is to obtain the longest life from the parts and the longest service between shoppings as well as the highest efficiency. Repairs can be best and most cheaply made if they are centralized as much as possible in one shop. This permits the shop to be fitted with the tools specially adapted for work on internal combustion engines and confines the work to a fewer number of machinists.

It has been pointed out above that owing to the size of the engine, some of the rail cars have virtually become locomotives and possess many characteristics that are common to the really large units. Realizing that knowledge gained by the consideration of the large units is applicable to a large degree to the cars, and although the subject of the paper is « Rail motor vehicles » it is thought permissible to include the oil-electric locomotive.

One of the most economical applications of the oil engine on steam railways is in yard switching service. This has been demonstrated on several railways in the United States by locomotives weighing about 70 tons, and having engines of from 300 to 600 H. P. with electric drive. A fact that is not always appreciated is that the average power developed by a steam switcher is a very small proportion of its maximum.

This is illustrated in figure 1 which is a chart based on actual indicator diagrams taken on a steam switcher in yard service throughout fifteen consecutive hours. The information was collected during an electrification study of a terminal on the Canadian National Railways, and is, perhaps, unique.

The chart shows :

a) Low average horsepower — 66.7 as compared with a probable 800 H. P. maximum;

b) Short peak load periods;

c) Low overall thermal efficiency — 1.9 %.

The wheel rim horsepower of a 450-H. P. oil electric, 65-ton switcher, at 5 and 10 miles per hour, is represented by the horizontal lines and clearly indicates how a relatively small locomotive can satisfy all the requirements, except during the few peak load periods. The time lost in working the peak loads at the necessary reduced speeds will be offset by its greater flexibility of operation and higher rate of acceleration.

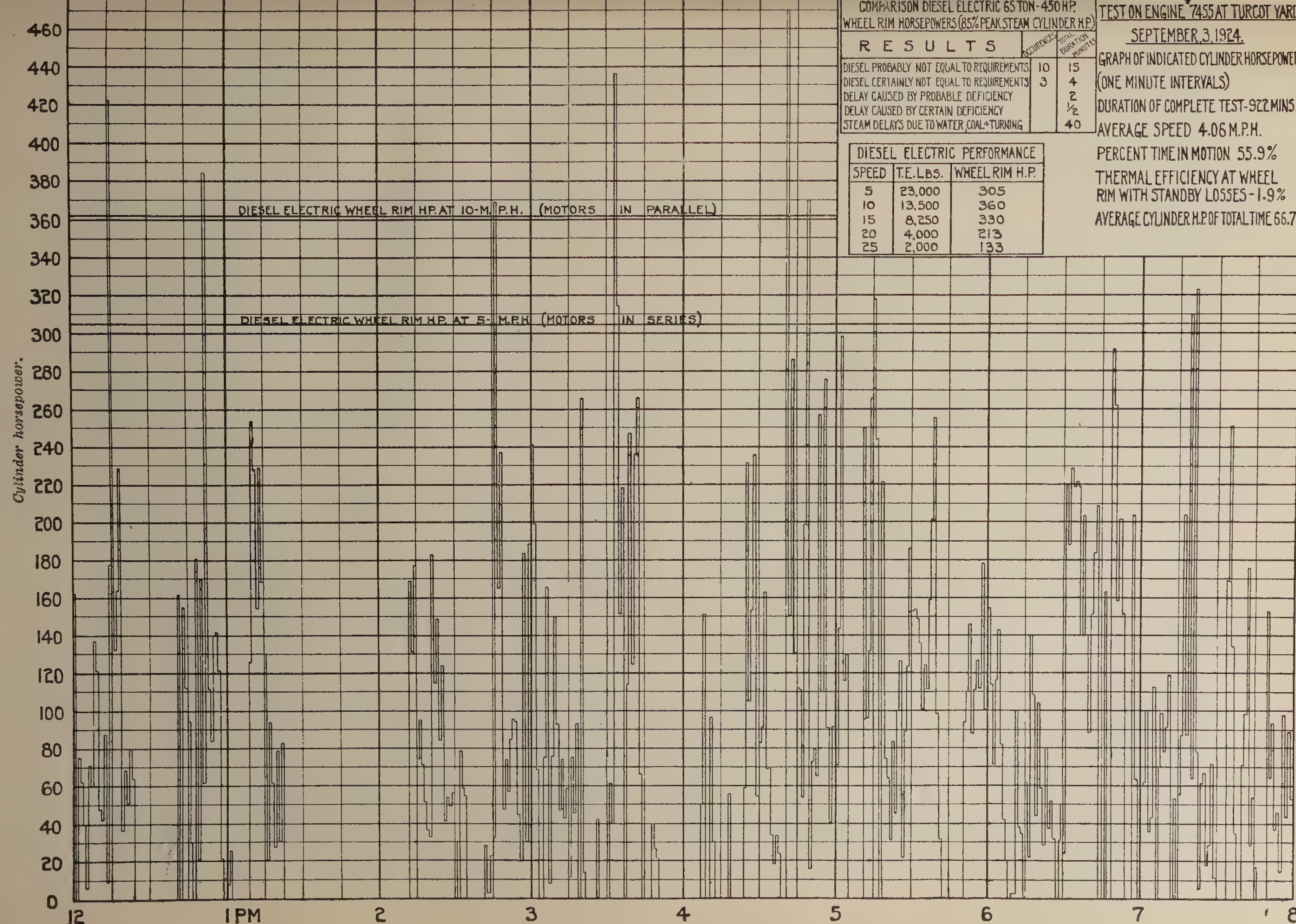

Fig. 1. — Typical portion of complete chart.

With overall efficiencies for this class of work of 21 % for oil electric and 1.9 % for steam, as above, the ratio of fuels for a given amount of work performed will be 11 to 1. That means that there would be a saving of $ 26.00 per 24 hours, based on the chart, or $ 7 800 in a year of 300 days, which represents about 9 % on the entire capital cost of the oil-electric locomotive.

Each terminal, of course, forms a distinct problem, but the saving in fuel is not the only economy resulting from the adoption of the oil engine locomotive. There is a reduction in the number of units required as two oil-electric, at the least, will be equivalent to three steam locomotives. This means lower wages and smaller shop facilities. The elimination of coaling plants, ash handling plants, water stations and the general simplification of the engine terminal is difficult to express in savings.

The Canadian National Railways have recently completed two locomotive units each having a maximum overload rating of 1 520 H. P. They have a 4-8-2 wheel arrangement and weigh 167 tons and are generally as shown in outline drawing, figure 2. The chief items of equipment in each cab consist of a Beardmonre 12-cylinder Vee engine, 12-inch bore, 12-inch stroke, developing 1 330 normal H. P. (1 520 maximum H. P.) at 800 revolutions per minute, direct connected to a Westinghouse D. C., 750-kw., 900-volt generator. There are four motors connected in pairs in permanent series and each motor drives an axle through two flexible gears. An auxiliary generator is mounted on the main generator shaft and acts as an exciter as well as to supply current for the air compressor motor and for battery charging, when the engine is running at other than idling speed. When idling, the battery charging and air compressor supply are provided from the main generator, which is fitted with a series field suitable for this purpose.

The engine speed is changed and the electrical circuits are controlled by a drum type of controller fitted with four handles which functions as follows :

No. 1 — operates the electro-pneumatic reversers to select the direction of movement.

No. 2 — establishes the generator and traction motor field circuits and applies low voltage to the motors, and also raises (or lowers) the engine speed through its full range.

No. 3 — increases the generator voltage to its full value and establishes the shunt field circuits on the traction motors (for both cabs when the two are operating connected together).

No. 4 — is similar to No. 2 and is used for the remote cab only, when operating coupled.

The range in engine speed is from 300 to 800 revolutions and is accomplished by means of a small motor which is connected to the governor through a worm and gears, and changes the governor speed setting. There is a definite period of critical shaft vibration within this range but by means of suitable contacts on the controller drum, the engine speed control motor is prevented from stopping at an engine speed within this critical period. As the engine goes up or down throughout its speed range in about seven seconds, the time in passing through the critical is very short, and the amount of work performed by the damper is of short duration.

These two locomotives were built to be operated in both freight and passenger

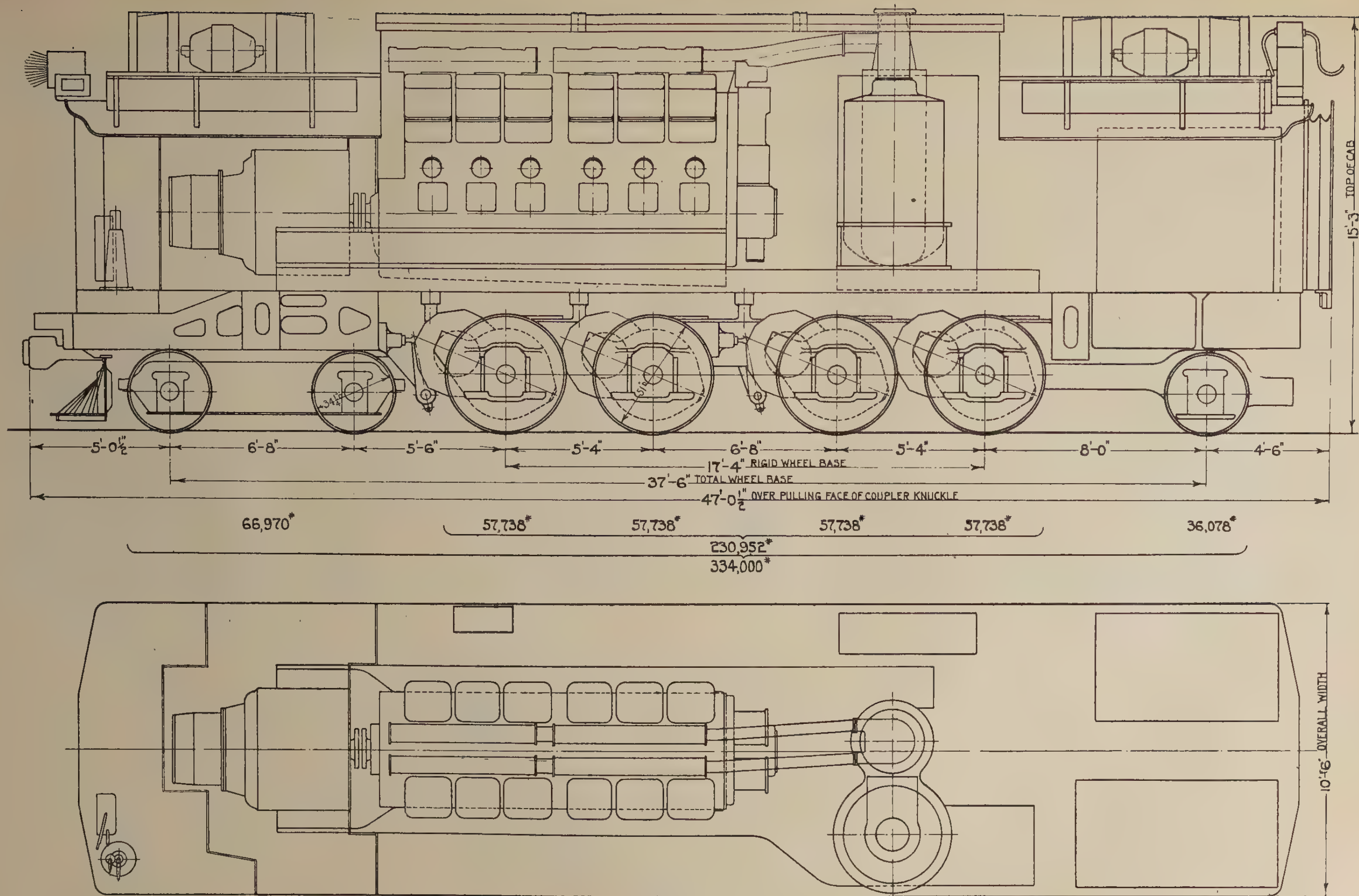
15'-3" TOP OF CAB
5'-0½"
6'-8"
5'-6"
5'-4"
6'-8"
5'-4"
8'-0"
4'-6"
17'-4" RIGID WHEEL BASE
37'-6" TOTAL WHEEL BASE
47'-0½" OVER PULLING FACE OF COUPLER KNUCKLE
66,970*
57,738*
57,738*
57,738*
57,738*
36,078*
230,952*
334,000*
10'-6" OVERALL WIDTH

Fig. 2.

Oil electric locomotive.

Total weight : 668 000 lb.
Weight on drivers : 461 904 lb.
Number of driving wheels : 16. — Diameter : 51 inches.
Two 1 330-H. P. Beardmore oil engines.
Two No. 478 West. generators — Yg-8 aux. gen's.
Eight No. 359 West. railway motors. 22 : 69 gear ratio.

Steam locomotive No. 6000.

Total weight : 594 860 lb.
Weight on drivers : 231 370 lb.
Number of driving wheels : 8. — Diameter : 73 inches.
Diameter of cylinders : 26 inches. — Stroke : 30 inches.
Steam pressure : 210 lb. per square inch.
Fitted with superheater.

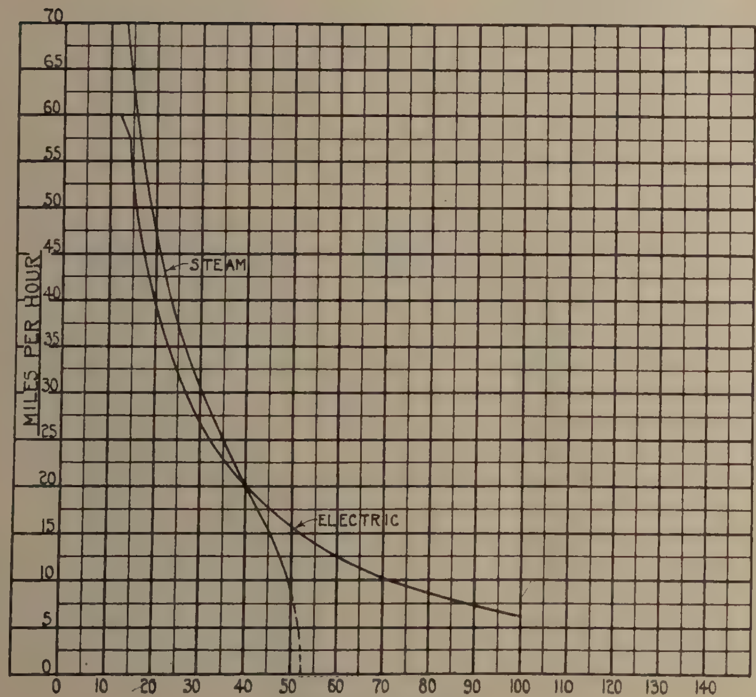

Fig. 3. — Tractive effort curve.

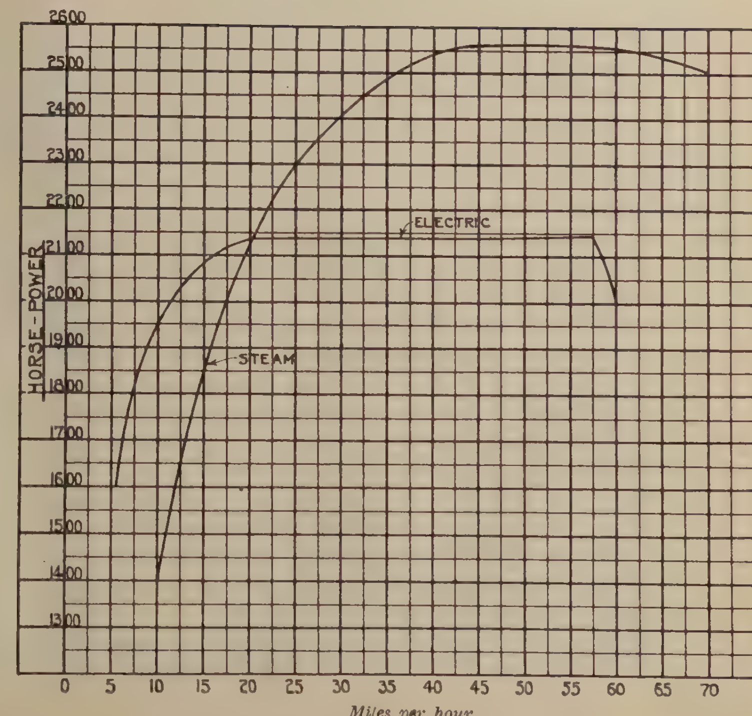

Fig. 4. — Horsepower curve.

service and were, therefore, fitted with train heating equipment. These consist of a Clarkson oil-fired thimble tube boiler having a steam capacity of 2 500 pounds per hour and a Clarkson waste heat boiler of the same type which will generate 1 000 pounds of steam per hour. The waste heat boiler acts very effectively as a silencer and can be operated dry, when steam is not required.

A torque governor is used to prevent overloading the engine by reducing the main generator field strength when full load has been reached. It is a small motor designed so that its field and armature currents are proportionate to those in the field and armature of the main generator. The torque on its armature will, therefore, be proportionate to the full engine load. The movement of the armature is limited to a few degrees by a helical spring, in such a way as to make or break a circuit, by a contact carried on its shaft. This circuit controls contactors which insert or shunt out resistance in the main generator field. The engine is started by motoring the generators off the storage battery. A separate drum switch is located in the engine room by which the necessary starting circuits are controlled. A 110-volt, 375-ampere-hour lead battery is used.

Data on the performance of one of these locomotive units is contained in :

TABLE IV.

Summary of performance from 20 November, 1928 to 31 May, 1929.

Oil electric locomotive 9 000. — 4-8-2 — 1 330 H.P. — 167 tons.

—	Demonstration service.	Freight service.	Passenger service.	Total to date.
Locomotive-miles	1 283	1 158	7 735	10 176
Passenger car-miles	...	...	32 994	32 994
Average train weight including locomotive (tons)	840	1 526	410	592
1 000 ton-miles	1 078	1 767	3 171	6 016
Fuel used	1 744	2 252	11 812	15 808
Average mileage per gallon (fuel)	0.74	0.52	0.65	0.65
Gallons per 1 000 ton-miles (fuel)	1.62	1.27	3.73	2.63
Lubricating oil used (gallons)	45	81	253	379
Average mileage per gallon (lubricant)	28.50	14.30	30.60	26 90
Ratio lubricating oil to fuel	2.58 %	3.59 %	2.14 %	2.39 %

With fuel — 6.5 cents per gallon, — lubricating oil — 70 cents — — } Costs per 1 000 ton-miles are :
Fuel : 17.0 cents. — Lubricating oil : 4.2 cents.

Comparison with the figures given by Mr. Tanouschevesky in his paper « Experiments with Diesel-engine driven locomotives on Russian Railways » before the Power Conference in London in 1928, shows the following :

TABLE V.

Rouble = 48 cents.
Kilometre = 0.62 miles.
Ton = 2.200 pounds.
Kilogramme = 2 2 pounds.

—	Russian.		Canadian National.	New York Central.
	No. 2. Diesel electrical.	No. 5. Diesel mechanical.	9 000	1 500
Fuel per 1 000 ton-miles . . .	15.5 cents.	13.8 cents.	17.0 cents.	Not yet available.
Lubricating oil per 1 000 ton-miles	3.4	3.2 —	4.2 —	Do.

Design characteristics of the Russian locomotives No. 2 and No. 5 (previously shown as No. 3), the Canadian National Railways No. 9000, and New York Central No. 1500 are given in table VI.

The fuel and oil consumption for the New York Central locomotives are not available and cannot, therefore, be shown in table V.

Tractive effort and horsepower curves of the double oil-electric locomotive compared with those of a steam locomotive of the 6 000 class are shown by figures 3 and 4. Below 20 miles per hour the oil-electric has considerable advantage in tractive effort and is able to develop greater horsepower, which is available for acceleration, than the steam. Between 20 and 57 miles per hour the oil-electric horsepower is practically constant but above this speed, corresponding to maximum voltage on the motors, the horsepower falls off rapidly. In order to utilize full engine horsepower at higher locomotive speeds, it would be necessary to change to a higher gear ratio.

In conclusion it may be pointed out as an indication of further interest and activity in this subject, that the Reading Company (U. S. A.) has very recently put in service a motor rail car of 300 nominal horsepower of the high pressure, airless injection, light weight type, manufactured by the Westinghouse Electric and Manufacturing Company, and others are said to be on order.

Strong efforts are being made both in America and Europe, some with fair success, to apply the oil engine to aircraft and to highway vehicles. Its advantages are particularly recognized in flying. These activities are most welcome. The more varied the applications and the greater the number of engineers interested in the development, the sooner will there be an accumulation of reliable data, based on a broader experience, all of which will materially assist the railway engineer in the solution of his particular problems.

TABLE VI.

Design characteristics.

LOCOMOTIVE NUMBER.	Russian. No. 2.	Russian. No. 5.	Canadian National. No. 9000.	New York Central. No. 1500.
Wheel arrangement	2-10-2	4-10-2	4-8-2	4-8-4
Weight per H.P., lb.	293	293	220	401
Weight per driving axle	38 400	38 800	58 000	46 250
Diameter of driving wheels.	49″	52.5″	51″	44″
Fuel supply, tons.	6.6	3.8	4	3.34
Design speed, miles per hour.	31	30	65	60
Type of engine	4-cycle, Man.	4-cycle, Man.	4-cycle, Beardmore Vee.	4-cycle, McIntosh & Seymour Vee.
Number and size of cylinders.	6×17.71×16.52	6×17.71×16.52	12×12×12	12×14×18
Maximum brake horse power.	700/1 200	700/1 100	1 520	900
Revolutions per minute.	300/450	300/400	800	310
Fuel injection.	Air.	Air.	Airless.	Air.
Engine starting.	Compressed air.	Compressed air.	Electric.	Compressed air.
Engine weight, tons	27.5	27.5	17.4 (including underbed).	45
Number of generator	1	...	1	1
Voltage	600/1 000	...	900	565
Amperage	1 200	...	1 300	1 000
Connection with engine.	Direct.	...	Direct.	Direct.
Number of motors	5	...	4	4
Connection with mains.	Parallel.	...	Series parallel shunt field.	Series parallel. Parallel. Parallel with reduced fields.
Gear ratio.	1:6.14	...	1:3.14	1:3.45
Motor output, 1-hour rating.	5×142 kw.	...	500 volts-900 amperes at 500 revolutions per minute.	415 H.P. at 600 volts.

APPENDIX.

AFRICA.

Name of railroad	Gold Coast Government Railways.	South African Railways & Harb
Gauge	3 ft. 6 in.	(B. G.) 3 ft. 6 in., (N. G.) 2 feet.
Maximum grade	1.25 % for 2 070 feet.	(B. G.) 2 ½ % for 12.225 m (N. G.) 2.63 % for 2.9 miles.
Maximum curvature	6 degrees.	(B. G.) 19.1 degrees; (N. G.) degrees.
Type of motor car	Steam rail car, chain drive.	Steam and gasoline rail cars, all chanical drive.
Description :		Car No. 8 (B.G.). Car No. 501 (N.G.). Car No. 10 (B
Seating capacity	52 third class.	40 or 17 60
Baggage compartment	Yes.	12 000 lb. Yes. Nil.
Mail	Nil.	Nil. Nil. Nil.
Control station	Double end.	All single end.
Weight in lb. (empty)	45 000 approx.	26 125. 14 750. 26 93
Engine horsepower	100 B. H. P.	2-74 H. P. 60 H. P. 2-90 H.
Advantage of types selected	...	Advantages of steam over gasoli coal fuel cheap, steam flex absence of gear boxes and clut
Disadvantage	...	All cars in service, more or les an experimental nature.
Reasons for this selection	To provide auxiliary passenger services to run at 1/5 cost of steam train.	Car No. 8 high powered car requ for milk traffic on heavy gr line. Car No. 501 Experiment and to place steam train for light tra
Maximum speed	35 miles per hour.	All cars 50 miles per hour on t
Schedule speed	20 miles per hour.	23 to 29 miles per hour.
Number of crew	3.	2.
Period between general overhaul	Every 12 months.	Service repairs maintained at ing depot.
How is service maintained during overhaul period?	Steam locomotive.	Steam locomotive.
Fuel	Coal.	Gasoline.
Miles per Imperial gallon	...	Twin engines, 6 to 8. Single engine
Lb. per mile	11.99.	...
Short ton miles per Imperial gallon	...	Car No. 8. Car No. 501. Car No 104.5 73.75 107.7
Short ton miles per lb.	1.8675.	... ...
Lubricating oil :		
Miles per Imperial gallon	125.5.	Varies, one case 344 and ano 25 ½.
Crew wages	Engineer, Fireman: $ 2.25 per day. Traffic staff : $ 487 per year.	$ 117 per month.
Maintenance per motor train mile	$ 0.025.	New car $ 0.14; old car $ 0.1275.
Rate of depreciation	580 000 miles.	330 000 miles.
Capital cost	$ 21 394 which includes $ 487 spares and $ 1 880 freight.	Car No. 8. Car No. 10. Car No. $ 14 750. $ 20 035. $ 16 6
Total operating cost per motor train mile without interest or depreciation.	$ 0.122.	Car No. 8. Car No. 10. Car No. $ 0.4772 $ 0.34. $ 0.14
Total operating cost of steam train mile replaced.	$ 0.6414.	Between $ 0.48 and $ 0.60.

AFRICA *(continued)*.

of railroad	**Egyptian State Railways.**	**Lourenço-Marques Rlys. & Harbours.**
	4 ft. 8 ½ in.	3 ft. 6 in.
num grade	0.67 % for 1 427 feet.	2 % for 1 836 feet.
num curvature	7.15 degrees.	7 degrees.
of motor car	Steam rail cars, mechanical drive by gearing on one axle of driving truck.	Steam rail car, mechanical drive.
iption :	*1st class* — *2nd class* — *3rd class*	*1st class* — *2nd and 3rd class (natives).*
ng capacity	21 — 28 — 70	9 — 27
ige compartment	Nil.	8 feet × 11.8 feet.
	Nil.	Nil.
ol station	Double end.	Single end.
ht in lb. (empty)	80 000.	...
ie horsepower	110 H. P.	100 H. P.
ntage of types selected	Obvious.	Cars not in service yet.
lvantage	...	...
ons for this selection	Simplicity and steam operation understood by engineers.	Cheap coal, therefore, steam more economical than any other system, also understood by engineers.
mum speed	37.28 miles per hour.	...
lule speed	...	...
ber of crew	3.	3.
d between general overhaul	Boilers washed out every 2 or 3 days.	...
is service maintained during erhaul period?	By spare cars.	...
	Coal.	Coal.
per Imperial gallon	...	...
er mile	17.74.	...
t ton miles per lb.	2.26.	...
icating oil :		
per Imperial gallon	...	...
wages	...	...
tenance per motor train mile	...	...
of depreciation	...	2 361 320 miles.
tal cost	$ 30 000.	$ 21 870.
l operating cost per motor train le without interest or depreciation.	Not in service long enough.	...
l operating cost of steam train le replaced.	Passenger train, $ 1.122.	$ 1.6.

AUSTRALIA.

Name of railroad	New South Wales Government Railways.	..
Gauge	4 ft. 8 ½ in.	..
Maximum grade	2 ½ % from 1/8 to 7 miles.	..
Maximum curvature	7.15 degrees.	..
Type of motor car	Gas-mechanical through a clutch, 4-speed gear box to final drive operating a single axle.	...
Description :		
Seating capacity	50.	...
Baggage compartment	9 000 lb.	...
Mail	Nil.	...
Control station	Double end.	...
Weight in lb. (empty)	23 000.	...
Engine horsepower	113.5 H. P.	...
Advantage of types selected	Double end control, and same car speed, in either direction.	...
Disadvantage	Minor defects only.	...
Reasons for this selection	Bad water conditions giving trouble in steam engine operation.	..
Maximum speed	55 miles per hour on level track.	...
Schedule speed	35 miles.	...
Number of crew	2.	...
Period between general overhaul	50 000 miles.	...
How is service maintained during overhaul period?	Out of 32 rail cars, 2 are allocated for relief purposes.	...
Fuel	Gasoline.	...
Miles per Imperial gallon	6.5 without trailer.	...
Lb. per mile	...	...
Short ton miles per Imperial gallon	74.75.	...
Lubricating oil :		
Miles per Imperial gallon	320.	...
Crew wages	Engineer and conductor, $ 0.0916 per train mile.	...
Maintenance per motor train mile	$ 0.048.	...
Rate of depreciation	Machinery 10 %. Car body 3.5 %.	...
Capital cost	Rail car $ 24 786. Trailer $ 11 396.	...
Total operating cost per motor train mile without interest or depreciation.	$ 0.285.	...
Total operating cost of steam train mile replaced.	$ 0.60.	...

CANADA.

me of railroad	Canadian National Railways.		
uge	4 ft. 8 ½ in.		
ximum grade	2 % for 3 miles.		
ximum curvature	Designed to take a 23-degree curve.		
pe of motor car	Oil electric, equipped with 4-cycle high pressure, airless injection engine with 8 1/4-inch bore and 12-inch stroke, direct coupled to generator. Electric drive.		
scription :	*a*) 4-cylinder engine car.	*b*) 6-cylinder engine car.	*c*) 8-cylinder engine car.
mber in service	7.	5.	2.
ating capacity	42.	57.	121 to 126.
ggage compartment	24 ft. 4 in. × 9 ft. 5 in.	27 ft. 3 in. × 9 ft. 6 in.	16 ft. 6 in. × 10 ft. 4 in.
il	Nil.	Nil.	Nil.
trol station	Double end.	Single end.	Double end.
ight in lb. (empty)	101 000.	141 400.	188 000.
iler weight in lb. (empty)	52 600.	55 200.	77 900.
gine horsepower	200 brake horse power at 800 revolutions per minute.	320 brake horse power at 800 revolutions per minute.	400 brake horse power at 700 revolutions per minute.
vantage of types selected	Flexibility of control, acceleration characteristics similar to electric, low maintenance, double end control allows motor car to be worked on any section of railway.		
sadvantage	Relatively high cost.		
asons for this selection	Dependability, cheapness of fuel oil, absence of fire hazard, high thermal efficiency of oil engine.		
ximum speed	60 miles per hour for all cars without trailers.		
edule speed	30 miles per hour.		
mber of crew	Engineer, conductor, baggageman.		
riod between general overhaul	Not established (probably after 175 000 miles).		
w is service maintained during overhaul period?	Steam train.		
el	Fuel oil, viscosity (100° S. U.) 60 to 70 seconds, 32° Beaumé.		
les per Imperial gallon	*a*) 4.	*b*) 3.	*c*) 3. All with trailers.
. per mile	...	...	...
ort ton miles per Imperial gallon	*a*) 307.	*b*) 295.	*c*) 399.
bricating oil :			
les per Imperial gallon	*a*) 60.	*b*) 33.	*c*) 27.
ew wages	*a*) $ 610 per month.	*b*) $ 708 per month.	*c*) $ 626 per month.
intenance per motor train mile	*a*) $ 0.17.	*b*) $ 0.17.	*c*) $ 0.43.
te of depreciation	Engine 6 %. — Other equipment. 4 %.		
pital cost	*a*) $ 60 000.	*b*) $ 85 000.	*c*) $ 131 000.
tal operating cost per motor train mile without interest or depreciation.	*a*) $ 0.368.	*b*) $ 0.413.	*c*) $ 0.677.
tal operating cost of steam train mile replaced.	$ 0.85 average.		

CANADA *(continued)*.

Name of railroad	Canadian National Railways.		
Gauge	4 ft. 8 ½ in.		
Maximum grade	1.4 % for 1 mile.	1 % for 550 yards.	1.7 % for 800 yards.
Maximum curvature	6 degrees.	8 degrees.	6 degrees.
Type of motor car	Gasoline electric equipped with gas engine direct coupled to generator electric drive.	Gasoline mechanical. Mechanical drive.	Nickel-iron storage ba ry. Electric drive
Description :			
Seating capacity	34.	55.	34.
Baggage compartment	13 ft. 8 in. × 8 ft. 3 in.	11 ft. 3 in. × 15 ft. 2 in.	Nil.
Mail	Nil.	Nil.	Nil.
Control station	Single end.	Single end.	Double end.
Weight in lb. (empty)	68 100.	66 400.	70 000.
Engine horsepower	120 B. H. P.	185 B. H. P.	450-ampere-hour batt 300 volts.
Advantage of types selected	Control flexibility, low maintenance, greater capacity than gasoline and battery cars.	Control flexibility, low maintenance.	Control flexibility, maintenance.
Disadvantage	Fire danger due to volatile fuel, cost, limited horsepower.	Fire danger due to volatile fuel, cost, limited H. P., weak transmission.	Battery capacity charging facilities mit car operation.
Reasons for this selection	To reduce operating expenses, relatively light passenger traffic on bra lines.		
Maximum speed	40 miles per hour.	40 miles per hour.	40 miles per hour.
Schedule speed	28 miles per hour without trailer.	25 miles per hour without trailer.	25 miles per without trailer.
Number of crew	2 or 3.	2.	2.
Period between general overhaul	About 2 years.	About 2 years.	About 2 years.
How is service maintained during overhaul period?	Steam train.	Steam train.	Steam train.
Fuel	Gasoline.	Gasoline.	Nickel-iron storage tery.
Miles per Imperial gallon	3.	7.	40 watt-hours per mile.
Lb. per mile	...	...	...
Short ton miles per Imperial gallon	102.15.	232.4.	...
Lubricating oil :			
Miles per Imperial gallon	70.	200.	..
Crew wages	$ 568 per month.	$ 440 per month.	$ 369 per month.
Maintenance per motor train mile	$ 0.25.	$ 0.10.	$ 0.15.
Rate of depreciation	Engine, 15 years; electrical, 25 years; car body, 4 ½ %.	Engine and mechanical equipment, 10 years; car body 4 ½ %.	Battery 16 %; equip and car 4 ½ %.
Capital cost	$ 50 000.	$ 25 000.	$ 45 000.
Total operating cost per motor train mile without interest or depreciation.	$ 0.626.	$ 0.32.	$ 0.28.
Total operating cost of steam train mile replaced.	$ 0.85 average.		

CEYLON.

ıame of railroad	Ceylon Government Railway.		
ıauge	Broad gauge (B. G.) 5 ft. 6 in. Narrow gauge (N. G.) 2 ft. 6 in.		
aximum grade	Broad gauge 2 % for 1.325 miles. Narrow gauge 1.25 % for 1.85 miles.		
aximum curvature	Broad gauge 9.65 degrees. Narrow gauge 24.8 degrees.		
ype of motor car	Steam rail cars with mechanical drive.		
escription :	Double unit (B. G.).	Single unit (B. G.).	Single unit (N. G.).
eating capacity	130.	66.	40.
aggage compartment	Nil.	Nil.	Nil.
ail	Nil.	Nil.	Nil.
ontrol station	All cars double end control.		
Veight in lb. (empty)	71 344.	46 816.	37 968.
ngine horsepower	100 B. H. P.	...	...
dvantage of types selected	More suitable and less costly to operate.		
isadvantage	Minor defects only, and are invariably found in new apparatus of this nature. Superheating coils in boiler subject to pitting.		
easons for this selection	Suitable for flagstops, low running costs, quick acceleration.		
Iaximum speed	35 miles per hour.		
chedule speed	25 miles per hour.		
umber of crew	Single unit, 3. Double unit, 4.		
eriod between general overhaul	Every 15 to 18 months.		
Iow is service maintained during overhaul period?	By spare cars.		
'uel	Indian coal used.		
Iiles per Imperial gallon	...		
b. per mile	11.		
hort ton miles per lb.	Double unit (B. G.) 3.21.		
ubricating oil :			
Iiles per Imperial gallon	...		
rew wages	\$ 111 to \$ 166.5 per month. Overtime after 8 hours duty (\$ 0.33).		
Iaintenance per motor train mile	\$ 0.10 including general repair.		
ate of depreciation	Approximately 300 000 miles.		
apital cost	(Double unit B. G.) \$ 29 000. (Single unit B. G.) \$ 17 500. (Single unit N. G.) \$ 16 500.		
otal operating cost per motor train mile without interest or depreciation.	\$ 0.41.		
otal operating cost of steam train mile replaced.	\$ 1.25.		

JAPAN.

Name of railroad	Chosen Government Railway.		Japanese Government Railways.		
Gauge	2 ft. 6 in.		3 ft. 6 in.		
Maximum grade	1.67 % for 2 969 feet.		16.7 % for 2 224 feet.		
Maximum curvature	14.48 degrees.		28.5 degrees.		
Type of motor car	Gasoline and steam. All mechanical drive.		Steam, all mechanical drive.		
Description :	a) Steam car.	b) Gasoline car.	No. 6400.	No. 6410.	No. 6450.
Seating capacity	64.	21.	38.	36.	44.
Baggage compartment	498 cubic feet.	Nil.	Nil.	Nil.	275 cubic feet.
Mail	Nil.	Nil.	Nil.	Nil.	Nil.
Control station	All single end.		All single end.		
Weight in lb. (empty)	114 240.	9 922.5.	38 140.	39 374.	37 920.
Engine horsepower	T. E. 4 529 lb.	20 H. P.	...	...	...
Advantage of types selected	Cheap coal, steam power therefore more economical than gasoline engines.		Cheap fuel, engineers familiar wit steam engine, cheap maintenanc repair.		
Disadvantage	...		...		
Reasons for this selection	Because steam power is cheap, steam cars built for broad gauge and gasoline cars for narrow gauge.		To reduce operating expenses.		
Maximum speed	All cars 34 miles per hour.		...		
Schedule speed	Steam 10 miles per hour. Gasoline 21 miles per hour.		...		
Number of crew	Steam, 3. Gasoline, 2.		...		
Period between general overhaul	Regularly but period not decided.		...		
How is service maintained during overhaul period?	Steam locomotive.		...		
Fuel	Coal and gasoline.		...		
Miles per Imperial gallon	...		...		
Lb. per mile	10.13.		...		
Short ton miles per lb.	5.64.		...		
Lubricating oil :					
Miles per Imperial gallon	a) cylinder oil 244. b) machine oil 183.		... ...		
Crew wages	$ 114.385.		...		
Maintenance per motor train mile	...		...		
Rate of depreciation	...		...		
Capital cost	Steam car $ 17 650. Gasoline car $ 3 400.		...		
Total operating cost per motor train mile without interest or depreciation.	...		...		
Total operating cost of steam train mile replaced.	$ 0.5575.		...		

INDIA.

Name of railroad	Eastern Bengal Railway	East Indian Railway.	Madras & Southern Mahratta Railway.
Gauge	Metre.	5 ft. 6 in.	5 ft. 6 in.
Maximum grade	0.562 % for 2 850 feet.	0.2 % for 4 500 feet.	1 % for 1 mile.
Maximum curvature	7.15 degrees.	7.15 degrees.	10.85 degrees.
Type of motor car	Steam rail car with mechanical drive.	Steam rail car with mechanical drive.	Steam rail car, ordinary steam locomotive forming one truck of car.
Description :			
Seating capacity	56.	*1st Class* 10; *3rd Class Men.* 76; *3rd Class Women* 14	84.
Baggage compartment	Nil.	408 cubic feet.	Nil.
Mail	Nil.	Nil.	Nil.
Control station	Double end.	Double end.	Double end.
Weight in lb. (empty)	45 000.	90 160.	97 200.
Engine horsepower	90 H. P. approx.	100 B. H. P.	...
Advantage of types selected	...	Not in service long enough to give satisfactory data.	No special advantages.
Disadvantage	...	Do.	Never proved satisfactory.
Reasons for this selection	Request of Railway Board.	Initial and operating cost being low as compared to Diesel and gasoline electric cars.	Only type available at purchasing time, 1907.
Maximum speed	40 miles per hour.	30 to 35 miles per hour.	35 miles per hour.
Schedule speed	30 miles per hour.	...	12 miles per hour.
Number of crew	2.	4.	4.
Period between general overhaul	...	...	Every 60 000 miles.
How is service maintained during overhaul period?	Steam locomotive.	Steam locomotive.	Steam locomotive and short train.
Fuel	Coal.	Coal.	Coal.
Miles per Imperial gallon	...	...	...
Lb. per mile	11.7.	25.2.	No satisfactory records available.
Short ton miles per lb.	1.925.	1.79.	...
Lubricating oil :			
Miles per Imperial gallon	40.5 including axle and cylinder oil.	35.3.	No satisfactory records available.
Crew wages	$ 92.87 per month.	$ 108.45 per month.	Do.
Maintenance per motor train mile	...	...	$ 0.045.
Rate of depreciation	...	...	Not considered.
Capital cost	$ 19 480 approx.	$ 48 655.	...
Total operating cost per motor train mile without interest or depreciation.	$ 0.149.	$ 0.112.	$ 0.33.
Total operating cost of steam train mile replaced.	...	$ 0.874.	$ 0.935.

INDIA *(continued)*.

Name of railroad	**Great Indian Peninsula Railway.**	**North Western Railway.**
Gauge	5 ft. 6 in.	(B. G.) 5 ft. 6 in. (N. G.) 2 ft. 6 i
Maximum grade	0.667 % for 3-1/4 miles.	(B. G.) 0.5 % for 2 000 feet. (N. G 3.3 % for 1 800 feet.
Maximum curvature	2.3 degrees.	...
Type of motor car	Steam rail cars with roller chain drive and a gear ratio of 1 to 1.5.	(B. G.) Steam rail cars. (N. G Gasoline rail cars. All mechanic drive.
Description :		*Gasoline cars.* a) b) c) d) · *Steam ca* e)
Seating capacity	Upper class. 10 · Lower class. 91	a) 5 · b) 3 · c) 13 · d) 19 · e) 86
Baggage compartment	4 480 lb.	Nil. · Nil. · Nil. · Yes. · Nil.
Mail	Nil.	Nil. · Yes. · Nil. · Nil. · Nil.
Control station	Double end also in centre.	All single end.
Weight in lb. (empty)	80 000.	4 500 · 7 240 · 12 280 · 16 000 · 67
Engine horsepower	100 B. H. P.	34 HP. · 47 · 50 · 85 · T. E. 11 312
Advantage of types selected	Not necessary to turn car at terminal.	Able to compete against road trar port and to give an accelerat postal service.
Disadvantage	Inability to attach a trailer in emergency. Engineer's cab separate from power plant. Engineer not aware of fireman's difficulties and relies on fireman for repair details. Sprockets results in heavy chain wear.	Physical characteristics of track p vent comparison between the t types of rail cars.
Reasons for this selection	High power weight ratio, light weight per passenger carried, low fuel consumption per ton mile.	All rail cars for quicker servi Steam cars for test purposes start a frequent service in count districts.
Maximum speed	30 to 35 miles per hour.	18 to 30 miles per hour.
Schedule speed	20 to 30 miles per hour.	...
Number of crew	3.	Gasoline car, 1. Steam car, 2.
Period between general overhaul	Every 12 months.	When necessary.
How is service maintained during overhaul period?	Lightest steam locomotive available and ordinary cars.	Steam locomotive and passeng train.
Fuel	Coal.	Coal and gasoline.
Miles per Imperial gallon	...	6.9.
Lb. per mile	10.96 to 14.	14.2.
Short ton miles per lb.	3.65 to 2.86.	2.36.
Short ton miles per Imperial gallon	...	55.2.
Lubricating oil : Miles per Imperial gallon	200 including axle and special crank-case oil.	a) 300 · b) 92 · c) 35 · d) 45 · e) not available.
Crew wages	$ 113.06 per month.	Gasoline car $ 74.55. Steam $ 79.55.
Maintenance per motor train mile	$ 0.0328.	Gasoline car $ 0.169. Steam car available.
Rate of depreciation	20 years.	...
Capital cost	$ 39 326.	a) $ 1 826 · b) $ 3 462 · c) $ 14 960 · d) $ 14 098 · e) $ 15
Total operating cost per motor train mile without interest or depreciation.	$ 0.06.	Gasoline car $ 0.116. Steam car available.
Total operating cost of steam train mile replaced.	$ 1.075.	(B. G.) $ 1.26 (N. G.) $ 2.10.

UNITED STATES OF AMERICA.

e of railroad	Baltimore & Ohio Railroad.	New York Central Lines.	Reading Company.
ge	4 ft. 8 ½ in.	4 ft. 8 ½ in.	4 ft. 8 ½ in.
imum grade	About 2 %.	About 2 %.	1.92 % for 700 feet.
imum curvature	About 14 degrees.	...	...
of motor car	(G-1-S) Gas. chain drive. (G-2) Gasoline gear. (GE-7) Gasoline electric.	Internal combustion engines with electric or mechanical drive.	Internal combustion engines with electric or mechanical drive.
ription :	(G-1-S) (G-2) (GE-7)	Gas-electric.	a) Gas-mechanical. b) Gas-electric.
ing capacity	22 67 46	a) 71 b) 21	32 39
gage compartment	Yes. 16'3" 17'03/4"	14'. 22' 4".	19'3" 14'4 ½"
	Nil. Nil. Yes.	Nil. 17' 1".	Nil. 770 cu. ft.
rol station	All single end.	Double end. Single end.	Single end. Double end.
ght in lb. (empty)	18 150 56 480 154 700	112 000. 159 040.	26 000 132 140
ne horsepower	65 190 300	250. 2-290.	68 3-120
antage of types selected	Gas-electric adopted account of smoother and quicker acceleration.	Economic use.	Operation economy and higher availability than steam.
dvantage	...	Specialized application.	None particularly.
ons for this selection	...	Light weight and low cost per H. P. Proven ability to handle work and reduce operating expenses.	Reduce operating cost of trains in passenger service.
imum speed / dule speed	Dependent on grade and character of service.	Dependent on power plant.	45 to 60 miles per hour without trailer.
ber of crew	2 or 3.	2 or 3.	3.
od between general overhaul	Various.	About every 2 years.	Every 80 000 miles.
is service maintained during erhaul period?	Steam locomotive.	Steam locomotive.	At one point spare rail car used, all others steam locomotive.
	Gasoline.	Gasoline.	Gasoline.
s per Imperial gallon	0.765.	2.	1.763.
per mile	...	...	...
t-ton miles per Imperial gallon	(G-1-S) 7 (G-2) 21.6 (GE-7) 59.1	a) 112 b) 159	a) 23 b) 116.5
icating oil :			
s per Imperial gallon	130.	...	99.7.
wages	$ 0.187 per train mile.	$ 20.75 per day or 100 miles.	$ 20.55 per 8-hour day.
ntenance per motor train mile	$ 0.051.	$ 0.05 to $ 0.07.	$ 0.08095.
of depreciation	Passenger car rate applied.	10 %.	...
ital cost	(G-1-S) $ 9 300. (G-2) $ 33 000. (GE-7) $ 42 500.	Single gas-electric $ 50 000. Dual gas-electric $ 65 000.	Gas-mechanical $ 17 000. Gas-electric $ 58 095.
l operating cost per motor train ile without interest or depreciation.	$ 0.347.	$ 0.60 to $ 0.65.	$ 0.3991.
l operating cost of steam train ile replaced.	From $ 0.90 to $ 1.05.	$ 0.90.	...

UNITED STATES OF AMERICA *(continued)*.

Name of railroad	Richmond, Fredericksburg & Potomac Railroad.		Wabash Railway.	
Gauge	4 ft. 8 ½ in.		4 ft. 8 ½ in.	
Maximum grade	0.8 % for 6 miles.		1.03 % for 1 200 feet.	
Maximum curvature	2 degrees.		9 degrees.	
Type of motor car	Gas-electric having two 300-H. P. engines, two generators and 4 motors.		Gas-electric, having a 200 H. P [engine], one generator and 2 mo[tors]	
Description :	Motor car.	Trailer.	Motor. Baggage.	Motor. Baggage-ca[r]
Seating capacity	41.	80.	No.	32.
Baggage compartment	Rack.	Rack.	49 ft. 03/4 in.	25 ft. 3 3/4
Mail	Nil.	Nil.	Nil.	Nil.
Control station	Single end.	...	Single end.	
Weight in lb. (empty)	146 400.	82 680.	76 560.	77 920.
Engine horsepower	2 300 H. P.	...	200 H. P.	200 H. P.
Advantage of types selected	Power applied evenly, acceleration is rapid and smooth, availability high and maintenance low.		Control flexibility and opera[ting] economy.	
Disadvantage	...		None have developed.	
Reasons for this selection	Experimental stage passed, service reliability, lower first cost than similar oil-electric types.		Operating costs lower than for s[team] train.	
Maximum speed	65 miles per hour with trailer.		50 miles per hour without tr[ailer]	
Schedule speed	...		25 to 35 miles per hour.	
Number of crew	4.		3.	
Period between general overhaul	...		Not decided.	
How is service maintained during overhaul period?	...		Steam locomotive.	
Fuel	Gasoline.		Gasoline.	
Miles per Imperial gallon	1.44 hauling trailer.		2.57	
Lb. per mile	...		...	
Short ton miles per Imperial gallon	95.4.		98.3.	
Lubricating oil :				
Miles per Imperial gallon	120.		101.	
Crew wages	$ 1 035 per month.		Engineer and conductor, $ 12.21 [per] 100 miles.	
Maintenance per motor train mile	$ 0.06.		$ 0.02414.	
Rate of depreciation	Electrical and mechanical equipment, 10 % per year. Car bodies, 4 ½ % per year.		Not yet estimated.	
Capital cost	Motor car, $ 70 000.	Trailer, $ 24 000.	$ 33 700.	
Total operating cost per motor train mile without interest or depreciation.	$ 0.966.		$ 0.3315 (including interest and [de]preciation).	
Total operating cost of steam train mile replaced.	$ 1.25.		$ 0.9173 (including interest and [de]preciation).	

[656 .215]

REPORT No. 2

(America, British Empire, China and Japan)

ON THE QUESTION OF RELATIONS BETWEEN RAILWAYS AND SEA PORTS (SUBJECT IX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) [1],

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Figs. 1 to 21. pp. 2270 to 2350.

The following general survey of the working of rail and sea borne traffic deals only with the question of ports where there is a large volume of business. General suggestions are made as to the best and most efficient arrangement of railway and port facilities and equipment, and as to the most rapid and economical methods of working the traffic. Brief reference is also made to the various methods of fixing charges and tariffs and other arrangements in operation for encouraging and facilitating the growth and transit of import and export business.

Railway concentration yards for port traffic.

Export traffic.

When general railway and industrial traffic is included on the same train with export traffic, it is essential that at some point on its journey the train should pass through a yard or yards where the export traffic can be separated from the rest of the traffic before being finally forwarded to the port. A yard where this work can be done is generally provided at or near a junction between the main lines of a railway system and the lines leading to the port.

In some cases the work of separation has to be done in a *through* railway junction yard which is also used for the purpose of marshalling general railway traffic. Such yards will seldom be found suitable for performing the detailed classification needed by the port traffic, and in cases where this method of working exists it is found necessary to provide in the vicinity of the port a reception and marshalling yard in which the port traffic collected at the junction yard can be sorted into the necessary units.

The case of a railway *terminal* yard is somewhat different, and such yards, if conveniently situated and in the neighbourhood of the port, can often be adapted and used for receiving and marshalling purposes if adequate sidings are provided for accommodating the port traffic as well as the general railway and

(1) This question runs as follows : « Relations between railways and sea ports : lay-out of maritime stations; arrangement of outer and inner basins so that the most efficient lay-out of sidings may be provided for working them; operating and rate fixing methods; loading and discharging appliances. »

industrial traffic. The nature of the terminal business is the same both for railway and port traffic, the difference being limited to the extent and number of the lines required for holding and separating the cars.

Generally, however, it will be found desirable to provide a concentration yard exclusively for port traffic. This is especially desirable, in fact almost indispensable for the efficient conduct of the business in the case of ports which deal with large quantities of bulk traffic, such as fuels, ores or grain. In such cases miscellaneous traffic from all parts of the railway system can be conveniently concentrated at a railway yard situated near the junction of the port lines, and can be transferred unsorted to the port yard. Full trains loads of traffic can also be sent from inland stations or other marshalling yards direct to the port yard, where the cars can be separated as required either for holding in sidings, for storing in sheds, for storing on open ground, for discharging on quay, or for direct loading to ship. In the case of direct loading to ship the cars may be sub-divided in the port yard according to the quay, the ship's berth, or even the ship's hatchway at which they are required, or, alternatively, it will frequently be found that the best arrangement is to perform the more detailed operations of sorting in special sidings provided for the purpose near to the quays or piers.

Under certain conditions several concentration yards are found to be desirable. This is particularly the case when the port covers a large area and there are considerable distances between the quays or piers; also where large volumes of distinct traffics, such as fuels, grain, oil and general goods, are each dealt with in different parts of the port; or again, when bulk commodities in considerable volume are hauled to the port by train services which are entirely separate from the train services used for other traffics. In such cases particular commodities would be dealt with in different yards, or, alternatively, different yards would serve the requirements of separate sections of the port.

It is, however, found that a single yard, where practicable, ensures the most economical staffing arrangements and the most expeditious and efficient regulation of the traffic. If, therefore, the volume of export traffic is within the economic capacity of a single yard, and if a single yard can be conveniently located for the business of the whole port, one yard only should be provided.

Import traffic.

Import traffic of a miscellaneous nature can be conveniently received and marshalled in an ordinary railway junction yard. The cars may be sent unsorted from the port to such a yard, where they can be combined with other traffic passing through the yard, and can be conveyed to inland destinations on the normal through and local train services. If, however, traffic is regularly landed at a port in large quantities for single inland stations or distributing centres, it will be found economical to form it into full train loads close to the port in sidings specially laid down, from which it can be despatched direct to destination.

General.

The provision of separate groups of sidings for inward and outward cars respectively, increases the speed of handling and the efficiency of the work. In cases where the concentration yard is situated

at some distance from the port, it is of great importance that additional outward and inward sidings should be provided near the quays. This provision is necessary to enable the jetties and quays to be cleared and supplied promptly and with the minimum of interruption to the working at the berth. Such sidings can also hold export traffic until it is finally marshalled as required for particular ships and particular hatchways.

Lay-out of concentration yards.

Yards should, if possible, be laid out in such a manner that the movement of the cars is continuous in either direction.

The reception lines should each be capable of holding a full train load. There should be a sufficient number of reception lines to receive the trains as they arrive without delay to following trains. From these lines, cars should be worked, if possible, by gravity or by propulsion over a hump into sorting sidings of sufficient number to allow of classification at one operation into the main groupings required.

In the case of export traffic such groupings will generally be :

1. Cars to be stored;
2. Cargo to sheds for storage;
3. Cargo to open storage ground;
4. Cargo to individual quays or berths.

In cases where still further sub-division is required, this should be effected by means of grids, working if possible by gravity, and leading to the storage sheds or quay lines.

In cases where import traffic is sorted at the port yard into train loads for various destinations, the layout of the yard should be on similar lines, the sorting of the traffic being in accordance with the routes of the trains and the order of the stations.

Inward and outward yards laid out in this manner can deal efficiently with upwards of 2 000 cars per 24 hours in each direction, provided the port or destinations further inland can dispose of the traffic at a similar rate.

Special concentration yards are required to deal with the export of bulk commodities, such as fuels, which are worked to the port in full train loads. In such yards the traffic is separated according to grades, ownership, or vessel, as the custom of the port requires.

In cases where the traffic exceeds 1 000 cars per day, a yard laid out on the lines described above will generally be found to be economical.

Disposal of discharged cars.

At ports where both import and export traffic is dealt with, cars that have been unloaded should as far as ever practicable be used for loading up imported goods, provided the cars are suitable for the traffic, and provided also that they are owned by the Railway Company serving the port or by some other company with whom the Company serving the port has reciprocal arrangements for the use of cars; unloaded cars which cannot be used for loading imported traffic should either be despatched to the concentration yard and there made up into train loads for inland destinations, or should be distributed direct from the port to other works in the vicinity for loading.

Ports served by several railway companies.

It is undesirable to provide separate concentration yards for each railway com-

pany in the case of ports served by more than one company. If the combined traffics do not exceed the economic capacity of a single yard, a common concentration yard for the whole of the traffic is likely to prove most economical and efficient.

If a single yard is provided in such circumstances, uniform and equitable arrangements must be made to ensure that all traffic passing through the port is worked without preference between the different Railway Companies.

Difference between inland yards and port yards.

In inland *through* marshalling yards traffic generally flows through the sidings continuously, the cars being re-assembled into fresh train load combinations and proceeding on their journey as early as possible. On the other hand, the majority of sea ports require yards in which traffic can be held in cars to await the arrival of ships or orders for shipment. The passage of traffic through the port yard is thus much less continuous than through an inland yard. Port traffic also generally needs more detailed classification than railway traffic passing through inland marshalling yards. There is no difference of principle in the design of port and inland *terminal* yards.

Separation of consignments en route.

The separation of consignments en route is undesirable, and it is the general practice to keep together throughout their journey cars containing a single consignment of traffic, particularly when the goods are all destined for one ship. Whenever practicable port traffic should be handled in complete train loads, especially in the case of traffic forwarded in bulk from starting point, such as minerals, grain, or fruit.

Arrangement of quays.

No hard and fast rule can be laid down for the arrangement of quays, but at the majority of the ports under consideration piers or jetties predominate. This is usually the case in tidal waters if there is sufficient water space of suitable depth. In enclosed docks, jetties are also provided in order to give the maximum quay space within the dock area. Such jetties are usually approximately at right angles to the bulk heads. Continuous quays are generally constructed without indentations. At berths within docks at which coal is shipped, convenience and economy of quay space are secured by arranging alternate berths with a projecting « T » head, so as to allow the ships to overlap. When jetties are provided in a dock care must be taken to leave ample room between the jetties to allow of the free movement of vessels, tugs, lighters and floating cranes.

Arrangement of quay lines.

It is found convenient to provide at least three or four parallel lines along the edge of the quays, jetties, or piers opposite each berth. This arrangement allows a number of cars to be placed alongside the ships at one time, and reduces the interruption of work to a minimum; the cars should be changed as far as possible during the time the working of the dock is suspended for meal intervals or at changing of shifts or else after the dock work has finished for the day; this arrangement of lines also allows shunting to be carried out on one or more of the quay lines without disturbing the loading or discharging on the other lines.

When a quay or pier provides accommodation for more than one ship it will be found advantageous to provide groups of sidings leading to or parallel with the quay where cars for import or containing export traffic can be assembled and from which they can be placed quickly on the quay, and in which discharged cars or cars containing imports can be accumulated to await removal to store grounds or sheds, or to the departure sidings for inland destinations.

Groups of such sidings leading to each berth will increase the rapidity of working both import and export traffic. Where jetties are provided space can frequently be found for such sidings either in the middle of the jetties or on the ground on each side of the curve of railway lines leading to the jetty.

Interruption of loading or unloading operations.

In some cases interruption to loading or unloading operations cannot be altogether avoided. It can, however, be reduced to a minimum by the provision of feed lines near the quays, as already described, by the introduction of switches at frequent intervals along the berth lines, by the use of capstans and bollards, or by the employment of tractors for short movements of cars near the ship's side. If tractors are used the ground must be level with the top of the rail so that the tractor can pass over the rails during shunting operations.

For bulk traffic, such as minerals for export, it is economical, where the levels are suitable or can be made suitable, to have adjacent to each berth a group of feed sidings on an incline of not less than 1 in 80. The sidings should be so arranged that wagons placed in them by locomotives will run by gravity to the discharging point, and after discharge will proceed by gravity into empty sidings either by a continuous grade or by a reverse grade and automatic switch. If the levels cannot be made suitable for working by gravity, electric or hydraulic capstans or continuous haulage devices will generally be found more economical for placing and removing individual cars than the continuous employment of locomotive power for this purpose.

Whenever possible quay or pier lines should be open at both ends so that cars that have been loaded or discharged can be removed at one end without interfering with those arriving alongside the ship from the other end. If it is unavoidable that the siding should be dead-ended, the inconvenience can be mitigated by providing at suitable points along the feed lines traversers or turntables by means of which cars can be removed or placed in position without unduly interfering with loading and discharging operations. This method of operation is, however, slower and less economical, both in working and in maintenance, than a system of sidings open at both ends which can be cleared and filled by locomotives, assisted if necessary by capstans. Traversers and turntables interfere with the free movement of cars along the quays, and although they occupy less space than switches, they form an obstruction when shunting operations are undertaken by locomotives.

Sheds.

Covered shed accommodation on quays or jetties is necessary for cargo which requires protection from the weather during the period between unloading and loading, or for cargo which is being col-

lected or re-conditioned, or for cargo awaiting forwarding orders. Sheds should be provided with a narrow raised platform outside the building, level with the car and shed floors. One or more lines should be provided at both sides of the sheds alongside the platforms referred to, and the quay should be equipped with moveable cranes capable of handling traffic between platform, and car and ship. Inside the sheds a sufficient number of overhead travelling bridge cranes should be provided for distributing and sorting the cargo, and these cranes should be so designed as to reach the whole of the shed floor space. When traffic has to be stored for lengthy periods it may be found convenient for the shed to be built with more than one storey, each floor being served by bridge travelling cranes capable of lifting and lowering cargo through hatchways or through side doors in the shed walls. In the latter case it will be found that cargo can be handled with a minimum of manual labour between cars on the outside railway lines and the shed floors, if the bridge cranes are provided with carriages designed with a revolving jib arm which can be projected through the side doors of the shed. The shed floors should be smoothly constructed, level and free from obstructions, so as to facilitate the movement of barrows either by hand or power. In some cases the whole of the sides of the shed are made of sliding doorways, so that traffic can be taken into and out of the sheds direct at any point throughout their length.

Overhead bridge cranes of the following speeds and capacities are found to be efficient for shed working :

—	Capacity.	Lifting speed per minute.	Longitudinal travel per minute.	Cross travel per minute.
Direct lift	2 1/2 tons.	42 feet.	240 feet.	95 feet.
Lift by jib	15 cwt.	96 —	250 —	90 —

Jetties.

The length and breadth of jetties is determined by the method of working employed at the port and the nature of the traffic dealt with. The breadth should be sufficient for at least three, or if possible, four lines opposite each berth, with space in the middle of the jetty, between the sets of lines serving each side of the jetty, sufficient either for storing cargo to wait shipment, or for the provision of storage sheds, or for standage lines for cars which are awaiting orders or waiting to be placed in position. In cases where a jetty is of sufficient length to accommodate more than one ship at one side, the jetty should be wide enough to allow of approach lines being so arranged as to give easy access to the more distant berths without disturbing shipping operations at the berths nearer to the bulk head. The detailed arrangements will vary according to the special requirements of the port and of the vessels using the port.

The length of the jetties should not be less than the average length of vessel calling at the port, and where accommodating more than one ship at one side

should be a whole multiple of the average length of vessel.

Conflict of railway and port interests.

From the replies received from the various railway systems little difficulty seems to be experienced as a general rule in working the traffic at ports so as to satisfy all the interests concerned.

Appliances on quays.

Cranes.

The best types of crane which are provided in the most modern installations for dealing with mixed traffic are those with electric luffing jibs varying in capacity from 1 1/2 tons upwards according to the weights of the units to be dealt with. The radius of the cranes provided depends on the size of the ships calling at the port and the number of the quay lines to be spanned.

The speeds of electric cranes vary downwards as the lifting capacity of the cranes increases.

The following capacities, speeds and reaches are considered to be representative of the best modern practice when electrically operated cranes are used :

Capacity, in tons.	Lifting speed. Feet per minute.	Slewing speed. Feet per minute.	Luffing speed. Feet per minute.	Travelling speed. Feet per minute.	Radius, in feet at hook.
1 1/2	200 to 400	400 to 450	150 to 200	60	20 to 60
3	150 to 200	400 to 450	150 to 200	50 to 60	20 to 50
7	60 to 100	300	100	50	25 to 50
10	50 to 60	300	100	40	27 to 50

Quay cranes should be capable of travelling by power and should span the lines clear of the cars. Cranes with luffing jibs are of great advantage; they enable cargo to be taken up and deposited at all points between the minimum and maximum circles of the crane's reach; they thus save time, reduce manual labour, and in some cases avoid the provision of special landing platforms. They are also very useful in avoiding the top hamper of vessels.

The number of cranes provided for each berth necessarily depends upon the type of vessels using the port. There should generally be a sufficient number of cranes to work one or two simultaneously at each hatchway of a normal ship. At berths where heavy cargo is regularly handled a high capacity crane may be needed. If the heavy lifts are infrequent, a floating crane is found economical and useful, as its use avoids the necessity of moving the ship to a shore crane of high capacity. The provision and relative placing of the cranes of various capacities depends entirely on the nature of the business and the frequency of the heavy lifts. For miscellaneous cargo the majority of the cranes should be of no greater capacity than the weights of the bulk of the packages which have to be lifted. The lower the capacity of the cranes, the greater the speed of working and the less the power expended. Three-ton cranes are usually adequate for general business,

including timber. Five-ton cranes are found to be efficient for heavy traffics, such as iron, steel, machinery, etc. Ten-ton cranes are needed for handling mineral traffic by means of 5-ton grabs.

Dual capacity cranes geared for two speeds are efficient, and the combinations likely to prove most useful are:

1 1/2 and 3 tons;
2 1/2 and 5 tons;
5 or 7 and 10 tons.

The radius of cranes should be sufficient to plumb with their full normal load both any part of the ship's hatchway and the cars on the set of railway lines furthest from the edge of the quay.

Special appliances.

There are many different types of appliances for the export of fuels in bulk, *e. g.*:

High level gravity staiths fitted either with gravity chutes, the shipping height of which can be adjusted, or with conveyor belts which are adjustable both in elevation, projection from the quay and in lateral movement fore and aft;
Hoists with chutes of which the shipping height is adjustable;
Belt conveyors with adjustable spouts and machinery of the « Mitchell » or «McMyler » type.

In some cases storage bins are also provided.

For imported ore and minerals, cranes with grabs or transporters with grabs are in general use. The latter appliances are especially useful where the cargo may have to be handled as occasion requires to or from ship, storage ground or lighter.

For the import of grain in bulk bucket elevating plant or suction plant is used, together with belt conveyors leading to storage silos.

For exporting grain storage structures filled by elevators and discharged to ship by belts and elevators are in use.

For discharging banana traffic elevators and belt conveyors are found to be both speedy and econominal.

For landing or loading oil and other liquids pipe lines between the ships and storage tanks are commonly used.

No general rule can be laid down as to the types of appliance to be adopted. Careful consideration has to be given to each individual case, the decision depending on the quantity of the commodity to be handled, the probable revenue to be derived, the contour of the land in the vicinity of the port, the area of land available, and the quality of the labour employed.

Tonnage per metre of quay.

It will be readily understood that the figures of quay capacity in terms of tonnage handled vary very greatly, the quantity depending on the nature and volume of the traffic, the regularity of occupation of the berths, the type of ship, and the efficiency of the appliances and labour employed.

In the handling of general cargo from 1 000 to 1 700 tons per metre of quay can be reached per annum; 20 000 tons of coal per metre of quay can be shipped per annum with high capacity appliances specially designed for the purpose.

Method of working the port.

When the Railway Company owns the dock, piers or quays at a port, it is the general custom for the Railway Company to provide not only the railway lines and

equipment but the port machinery also. In such cases the rail rates generally include conveyance to a point on the quay alongside the ship; additional charges, generally included in the dock tariffs, are raised either against shippers or shipowners, or both in respect of the use of shipping appliances and the labour involved in transferring the cargo to or from the ships.

The responsibility for carrying out the different operations at the port, and consequently the method of raising charges, vary considerably at different places. In many cases the stowage of cargo in ships is carried out by labour employed and paid for by the shipper or the shipowner, independently of the Railway Company or other Port Authority.

In cases where the port, including its rail facilities and equipment, is owned by an organisation other than the Railway Company, the charges for shunting and placing cars at the port are often raised entirely separately from the rail rate, but when in such circumstances the Railway Company works traffic over the port lines, the rail rate often includes such services; when the Railway Company performs services in this manner for the Port Authority, the latter pays the Railway Company for services rendered, the payment varying according to the number of cars dealt with and the nature and amount of work performed.

The railway charges for port services are usually included in the general railway accounts, in some cases being shewn in a separate section. For specific services over and above ordinary placing and removal of cars, special charges are raised, *e. g.* for the use of special appliances such as coaling, grain lifting and conveying apparatus; for the use of storage accommodation and for the special handling of cargo in store grounds and sheds. These special charges cover not only the use of the appliance but also the cost of the labour involved.

Organization.

Where the port is owned by the Railway Company, the organization of the traffic working is comparatively simple, as the railway port staff are in constant and direct communication with the railway staff; the whole organization being controlled from railway headquarters, all work is properly co-ordinated and the necessary services are impartially performed.

Where the port is controlled by an organization distinct from that of the Railway Company, it is often the practice for agents to be employed by the shippers or shipowners, whose duty it is to arrange with the staff of the Railway Company and also of the Port Authority for the forwarding of export traffic to the port, and for the supply of cars for imported traffic so as to arrive in due time for the ships for which they are required.

In some cases the port working is administered and the port staff appointed and controlled by a Joint Committee consisting of representatives of all the interested parties, *e. g.* Railway Company, Port Authority, Chamber of Commerce, shippers, shipowners, and labour organizations. In other cases the port is owned by a City or other Corporation, who receive and deliver traffic from and to the Railway Company at an exchange yard, and themselves work the port lines and the quays, sheds and appliances.

Arrangements for prompt loading and discharge of cars.

There is considerable variation at different ports in the methods adopted to

obtain prompt discharge and loading of cars and also in the charges raised for detention of cars. At some ports there are no definite regulations; in other cases the forwarding of traffic is regulated by arrangement, fixed quantities being allowed to come forward daily, and in such cases if these quantities are not exceeded no demurrage charge is imposed.

Free periods for detention of cars containing fuels vary very considerably, in some case up to 15 days from the date of arrival being allowed. In other cases the time for supplying railway cars for the loading of fuel, and the time for the removal from the loading points of private cars loaded with fuel, is determined by the approach to the port of the ship for which the fuel is required. In other cases a definite number of railway cars is allotted to a Colliery Company for carrying on its business, and in such cases, provided the Colliery Company does not exceed this number of cars, either loaded or empty, no demurrage charges are raised; the number of cars allotted in this manner to Colliery Companies is fixed in relation to the amount of business which the Colliery Company is doing, together with the distance of the colliery from the port; the number of cars allotted being varied from time to time in relation to changes in the volume of the business. In cases where cars belonging to private owners are used for dock traffic, they are of course not subject to charges for detention, but the raising of special charges in such cases for the occupation of siding accommodation in excess of a prearranged free period appears desirable in order to avoid congestion in concentration yards.

When stations sending cargo to the port are at some distance from the port, and when the arrival of shipping is irregular, it is not possible in all cases to coordinate the arrival of cargo with the arrival of the ship. In such cases steps have to be taken to release railway cars. In some instances this is effected by unloading export traffic to storage grounds, quays or sheds. In other cases the cargo is transferred to special dock wagons reserved for the purpose, charges being raised for the work performed. In other cases demurrage charges are raised by the Railway Company in connection with the railway cars either at a rate per car or in relation to the weight of the cargo. Owing to the variation of conditions at different ports, it is impossible to formulate definite rules suitable to all ports. It may be assumed that the varying arrangements adopted generally attain the desired result and effect a reasonably prompt liberation of cars.

Tariffs.

Tariffs may be divided into three general categories.

1. *Transit tariffs.*

Transit tariffs are based on a number of factors, and vary with the customs of the country. In some instances the charging powers of the Railway Company are regulated by the laws of the land. The fixing of transit tariffs in different countries is influenced by the value of the traffic, the length of the haul, competition between countries and between ports in the same country, and also competition between railways and other methods of transport. In some cases, in order to encourage export traffic, the rates are fixed at a lower level than the corresponding rates for domestic traffic.

2. Handling tariffs.

These are sometimes included in the throughout transit rate. In other cases they are raised separately. They are generally based on the cost and depreciation of appliances and on the labour costs involved.

3. Storage tariffs.

Storage tariffs generally take the form of rent for space occupied, and in addition if the work is done by the Railway Company or Port Authority a charge is usually raised for the labour involved in putting the goods into store and removing them from store; in other cases rent is based on the weight and nature of the traffic rather than on the space occupied. In some cases storage accommodation is owned by the traders themselves.

Direct tariffs from inland to overseas destinations.

Direct tariffs between inland stations and overseas centres are rare. On the few occasions when they are quoted they generally consist of the sum of the rail charge in the originating country, the sea freight, and the rail charge in the country of destination. In a few cases when the same authority owns the railway, the port and the ship, through tariffs are quoted between stations in different countries covering all the operations during transit.

Advising traffic movements.

In order to facilitate the transit of port traffic, it is generally consigned to an agent at the port or else the car is labelled to the ship by which the cargo will be exported.

A number of different methods are employed to keep the parties concerned advised of the information necessary for the despatch of traffic and to give prompt notice to shippers of the arrival of cargo at the ports. The procedure is generally of a simple and direct nature.

Performance of customs duties.

Enquiries shew that there is generally little to be desired as regards the arrangement of the customs services, but in one or two instances there seems to be some lack of co-ordination between the customs officials and the Railway and Port Authorities, which causes inconvenience in dealing with the cargo.

General conclusions.

The arrangement both of the Railway and Port equipment, including the type of appliances used, is largely governed by the contour of the land, and by the land and water space available. The methods of working and handling cargo also shew considerable differences in detail due to the nature of the cargo, the quality of the labour, and the varying climatic conditions.

The replies which have been received to the enquiries made reveal no serious difference of opinion among the Railway Companies in the different countries on any of the important questions of principle covered by the enquiry. There is general agreement on the fundamental principles to be observed in laying out a railway to deal with overseas traffic, in deciding upon the arrangements and equipment of seaports and in the methods of working traffic and raising charges.

APPENDIX.

Summary of replies to detailed list of Questions relating to question IX.

PART I.

Railway yards at ports.

QUESTION 1.

a) *Are the wagons led into a single concentration yard for the whole port, or are they led to several yards ?*

b) *Are there separate concentration yards near the port for inward and for outward traffics ?*

c) *Please give a plan of such yards, shewing the layout of the lines and sidings.*

London & North Eastern Railway.

Leith Docks. — Hull, King George Dock. — Immingham Dock. — Parkeston Quay :

a) *At Leith* there are two London & North Eastern (one of which is an overflow yard) and one London Midland & Scottish concentration yards.

c) See plan London & North Eastern Railway Company's yard (fig. 1).

a) *At Hull* there are two concentration yards, one for mineral and one for goods traffic some distance from the docks, at which traffic is sorted for the various docks. Traffic for King George Dock is led from these yards to a reception and sorting yard at that dock.

b) There are separate inward and outward yards at the goods and mineral concentration yards. At King George Dock there is one yard for both inward and outward traffic.

c) See plan Hull inward and outward goods yards (fig. 3).

a) *At Immingham.* — Yes.
b) There are separate yards.
c) See plan Immingham (fig. 6).

a) *At Parkeston Quay.* — Yes.
b) There are separate yards.
c) See plan Parkeston Quay (fig. 7).

London Midland & Scottish Railway.

Garston Docks, Liverpool :

a) One concentration yard at Speke junction sidings.
b) Yes.
c) See plan Speke junction yard (fig. 8).

Great Western Railway (Great Britain).

Cardiff Docks :

a) Several yards, which have been constructed as convenient having regard to the physical conditions.

b) Generally each concentration yard contains separate sidings for inward and outward traffics.

c) See plan Cardiff (fig. 11).

Southern Railway (Great Britain).

Port of Southampton :

a) All concentration and marshalling is done at Southampton Docks.

b) Yes, export at « A » and import at « B ».

c) See plan Southampton (fig. 15).

Canadian National Railways & Canadian Pacific Railway.

Port of Montreal :

a) Each railway has separate concentration yards.

b) No.

South African Railways & Harbours.

Port of Durban :

a) Single yard.

b) Yes.

Table Bay Harbour, Capetown :

a) A single yard consisting of six lines each capable of taking eighteen 40-foot vehicles, with a carrying capacity of 720 tons.

b) No.

c) See plan Capetown (fig. 16).

Gold Coast Government Railways.

Port Sekondi :

a) A single yard.

b) Separate reception, despatch and marshalling yards.

Sudan Government Railways and Steamers.

Port Sudan :

a) One marshalling yard.

b) Yes.

New South Wales Government Railways and Tramways.

Darling Harbour. — Darling Island. — Rozelle :

a) A single yard.

b) No.

c) See plan Rozelle (fig. 17) and Darling Harbour yards (fig. 18).

North Western Railway (India).

Port of Karachi :

a) Wagons are led to several yards after passing through the general sorting yard of the North Western Railway.

b) Yes.

Madras & Southern Mahratta Railway.

Mormugao Harbour :

a) and *b*) Export traffic is received at Vascodagama yard where manganese ore is dumped prior to shipment and other wagons are taken to the port and the produce is unloaded to shed for storage or sorting prior to shipment.

Import traffic is brought to Vasco. yard and there formed into trains.

Ceylon Government Railway.

Port of Colombo :

a) Wagons are consigned to « Port Commission Railways » which covers the whole port.

Federated Malay States Railways.

Port Sweetenham :

a) A single yard.

b) The marshalling yard serves both purposes.

New York Central Lines.

New York City Harbour. — Weehawken yard on the West side of the Hudson River and 60th Street yard on the East side of the River in New York City :

a) There are several yards due to the topographical condition of the harbour.

b) Yes.

Pennsylvania Railroad Company.

Port of Philadelphia for general traffic. — Port of Sandusky for coal traffic. — Port of New York.

Philadelphia :

a) A single yard.

b) Yes.

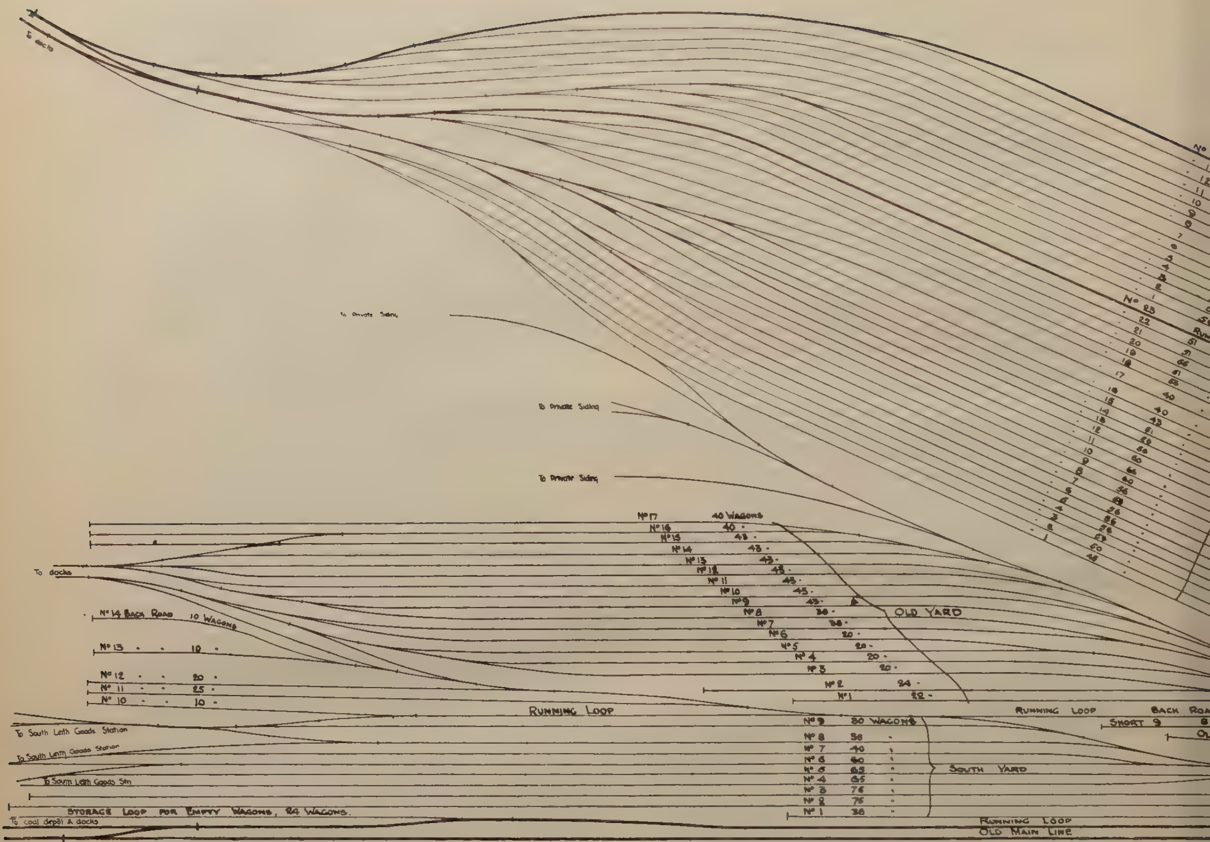


Fig. 1. — Diagram of marshalling yard at South

Sandusky :

a) A single yard.

b) Yes.

Port of New York :

a) There are several Pennsylvania Railroad terminals at New York. South Amboy is principally used for coal shipment. Greenville is used for float interchange with the New York, New Haven & Hartford Railroad, Long Island Railroad, and also for serving some of the Pennsylvania Railroad, New York, and Brooklyn piers, and is the principal terminal for handling domestic and foreign lighterage shipments. Harsimus Cove terminal is for pier freight, coal for bunkering, some lighterage freight and poultry shipments.

Answers based on Greenville terminal, unless otherwise specified.

b) There are separate receiving yards for Eastbound and Westbound cars. Eastbound cars are classified from this yard to float yards for loading on car floats; to lighterage yards for movement to lighterage piers; to grain yards for movement to grain unloader.

The Westbound yard has a receiving yard, a classification yard and a despatching yard.

London & North Eastern Railway, Scottish Area.

Baltimore & Ohio Railroad.

Port of Baltimore :

a) Several yards are provided : the yards at Curtis Bay and Locust Point are herein referred to.

b) The are separate groups of tracks for inward and for outward traffics.

Norfolk and Western Railway.

Lambert's Point. — Virginia and Norfolk Harbour :

a) There are separate yards owned by the various Railway Companies.

b) Yes.

Reading Company.

Port Reading, N.J. :

a) A single yard.

b) No.

Buenos Ayres Great Southern Railway.

Ingeniero White Port :

a) A single Junction yard made up of several yards.

b) One yard is used for import traffic and one for export traffic.

Buenos Ayres & Pacific Railway.

Madero Port at Buenos Ayres :

a) There are four separate Railway Companies. Each Company delivers to a group of sidings at the connecting point leading to a running line at each end.

b) No.

Japanese Government Railways.

Ports of Yokohama, Kobi, Warkamatsu, Muroran, Tobato, and Otaru :

a) The maritime station is generally constructed on a branch from the main line and the wagons to and from the maritime station are shunted in the yard at the junction station, along with other traffic. At the coal exporting ports Warkamatsu, Muroran, Tobato and Otaru, there is a yard within their compounds.

c) See plans of Tobato and Warkamatsu yards (figs. 19 and 20).

Railway Bureau, Government General of Chosen.

Ports of Jinsen, Fusan, and Genzan :

a) Generally a single concentration yard.

b) No.

South Manchuria Railway.

Port of Dairen :

a) A single yard.

b) No.

QUESTION 2.

a) *What quantity of traffic do you consider justifies the provision of a concentration yard at a port?*

b) *What quantity of traffic do you consider necessary to justify the construction of separate concentration yards for inward and for outward traffics?*

London and North Eastern Railway.

a) This depends on the proximity of the port to the concentration yard and the amount of accommodation in the vicinity of the quays.

b) Separate concentration yards are desirable.

London Midland and Scottish Railway.

a) Depends on the nature of the traffic dealt with and the distance and capacity of the nearest traffic yard.

b) For export and bunker coal traffic 50 wagons per day.

For outward traffic, in view of the proximity (5 1/2 miles) of Edge Hill yard, a separate concentration yard would be necessary for upwards of 150 wagons per day.

Great Western Railway (Great Britain).

a) When the traffic reaches such quantity that it cannot be dealt with on the lines at the quayside, a concentration yard becomes necessary.

b) Separate yards are usually a convenience, but the necessity is governed by local conditions.

Canadian National Railways and Canadian Pacific Railway.

a) and *b*) Impossible to generalise.

South African Railways and Harbours.

a) Depends on circumstances. It is considered that where conditions are similar to those at Durban that 50 000 tons per month would justify the yard.

b) There should be separate inward and outward sidings.

a) Where conditions are similar to those at Capetown concentration yards for large ports should consists of, say, not less than 15 roads, each road capable of carrying 800 tons of traffic giving an aggregate tonnage of 12 000 tons.

b) Under similar circumstances 6 000 tons of inward and 6 000 tons of outward traffic per diem should justify separate yards.

New South Wales Government Railways.

a) 500 cars per 24 hours.

b) 1 000 cars of inward and outward traffic combined.

North Western Railway (India).

a) A small concentration yard is considered necessary even for a very limited traffic.

Federated Malay States Railways.

a) Depends on the site of the port and the lay-out. A concentration yard is considered necessary if 40 000 tons of traffic per month is handled.

b) Depends on the traffic of the port. A yard which can be utilised for either inward or outward traffic is preferable so that if there is an overflow of inward or outward traffic operations are not delayed by having a transfer from yard to yard.

New York Central Lines.

a) Approximately 50 cars per day.

b) Depends entirely on maximum demand.

Pennsylvania Railroad Company.

For general traffic :

a) 200 cars per day.

b) 400 cars per day.

For coal traffic :

a) Any volume of traffic would justify concentration yards, the size depending upon the amount of traffic.

b) Separate yards should be provided in all cases.

Baltimore & Ohio Railroad.

a) The provision of a yard would be justified for one train in each direction daily, even though the yard consists of only two or three tracks.

b) It is considered advisable to provide separate track space for inward and outward traffic.

Norfolk and Western Railway.

a) A yard is necessary under any circumstances.

b) Inward and outward sidings are necessary.

Reading Company.

a) and *b*) This must be ruled by the various conditions obtaining at the port.

Buenos Ayres Great Southern Railway.

a) and *b*) This depends on local conditions and whether the port traffic interferes with the normal working of the yard at which port traffic is handled.

Buenos Ayres and Pacific Railway.

a) Depends on the classification required.

b) One yard preferable, but local conditions must be considered.

Japanese Government Railways.

a) The provision of a concentration yard at a port depends largely on whether there is suitable yard accommodation in the vicinity.

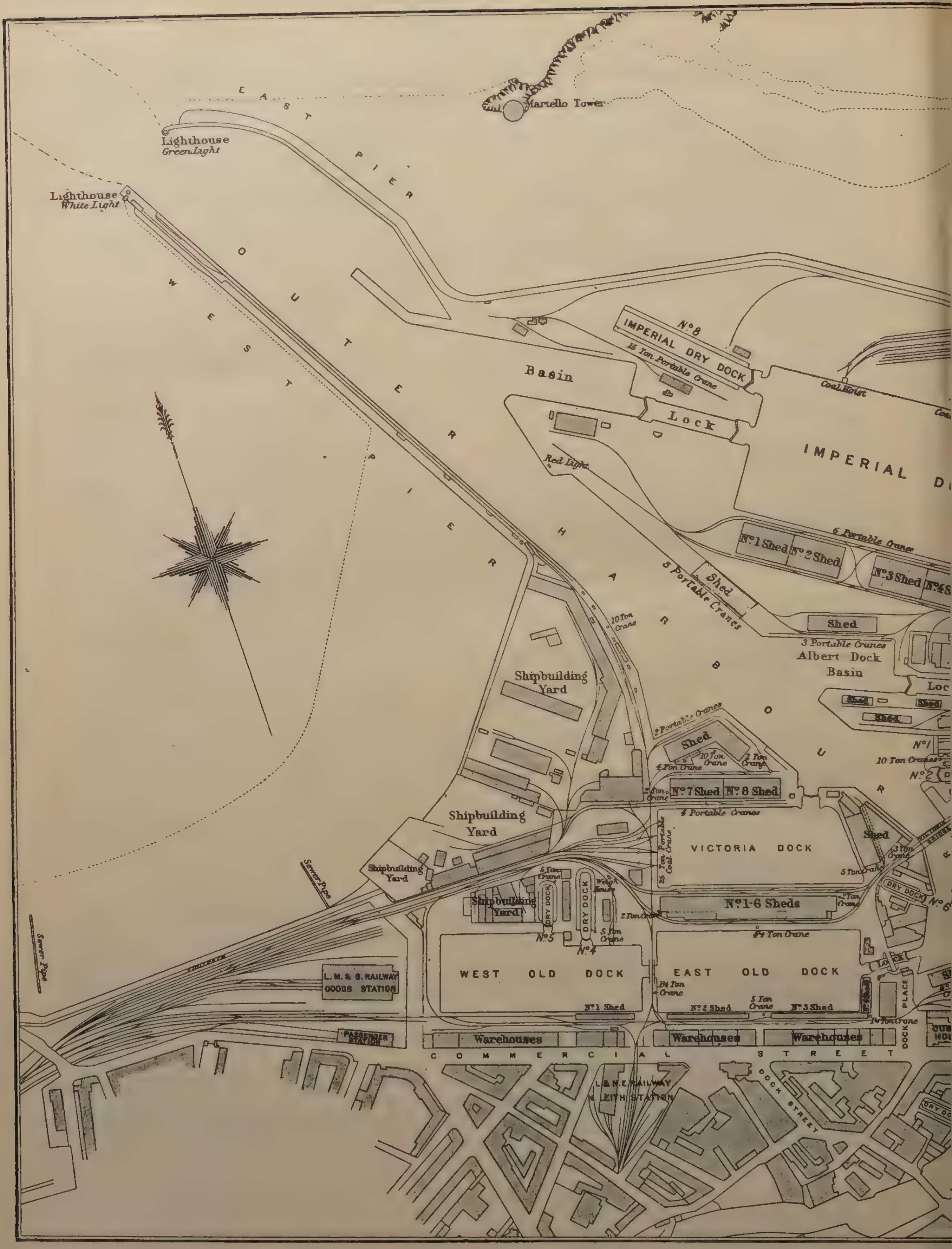
b) It has not been found necessary to construct separate yards for inward and outward traffics.

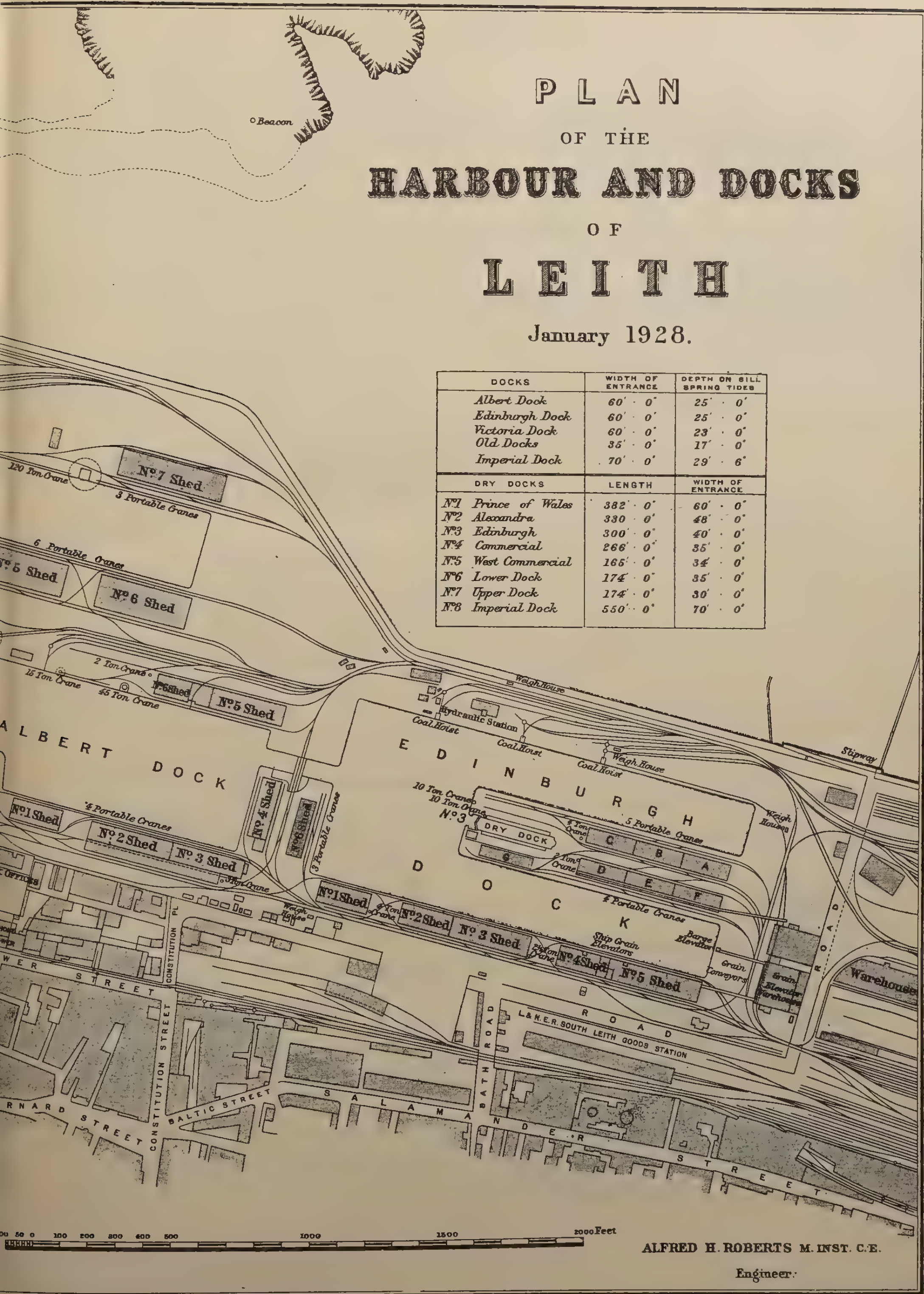
QUESTION 3.

When several railways serve the same port do you consider that each railway should have a separate yard, or do you recommend that a common yard should be used by all the railways ?

London & North Eastern Railway.

A common concentration yard is desirable.


EAST PIER
Martello Tower
Lighthouse
Green Light
Lighthouse
White Light
WEST PIER
OUTER HARBOUR
Basin
No. 8
IMPERIAL DRY DOCK
15 Ton Portable Crane
Lock
Coal Hoist
IMPERIAL D
Red Light
6 Portable Cranes
No. 1 Shed
No. 2 Shed
No. 3 Shed
5 Portable Cranes
Shed
10 Ton Crane
3 Portable Cranes
Albert Dock Basin
Shipbuilding Yard
2 Portable Cranes
Shed
10 Ton Crane
2 Ton Crane
No. 7 Shed
No. 8 Shed
4 Portable Cranes
VICTORIA DOCK
25 Ton Portable Coal Crane
Shipbuilding Yard
Shipbuilding Yard
Sewer Pipe
Shipbuilding Yard
DRY DOCK
DRY DOCK
No. 5
No. 4
Weigh House
5 Ton Crane
No. 1-6 Sheds
DRY DOCK
Sewer Pipe
L. M. & S. RAILWAY GOODS STATION
WEST OLD DOCK
EAST OLD DOCK
No. 1 Shed
No. 2 Shed
No. 3 Shed
PASSENGER STATION
Warehouses
Warehouses
Warehouses
DOCK PLACE
COMMERCIAL STREET
L. & N. E. RAILWAY N. LEITH STATION
DOCK STREET



DOCKS	WIDTH OF ENTRANCE	DEPTH ON SILL SPRING TIDES
Albert Dock	60' · 0"	25' · 0"
Edinburgh Dock	60' · 0"	25' · 0"
Victoria Dock	60' · 0"	23' · 0"
Old Docks	35' · 0"	17' · 0"
Imperial Dock	70' · 0"	29' · 6"

DRY DOCKS	LENGTH	WIDTH OF ENTRANCE
No. 1 Prince of Wales	382' · 0"	60' · 0"
No. 2 Alexandra	330 · 0"	48' · 0"
No. 3 Edinburgh	300' · 0"	40' · 0"
No. 4 Commercial	266' · 0"	35' · 0"
No. 5 West Commercial	165' · 0"	34' · 0"
No. 6 Lower Dock	174' · 0"	35' · 0"
No. 7 Upper Dock	174' · 0"	30' · 0"
No. 8 Imperial Dock	550' · 0"	70' · 0"

Lithographed by W. & A. K. Johnston Limited Edinburgh & London.

London Midland & Scottish Railway.

A single yard would undoubtedly be the most satisfactory arrangement, provided each railway had ready access.

Great Western Railway (Great Britain).

The governing consideration should be the convenience of working the port, and the ideal arrangement would be one yard in which the traffic should be deposited as required by the Port Authority.

Southern Railway (Great Britain).

A common yard is preferable.

Canadian National Railways and Canadian Pacific Railway.

Present system of independent yards works well.

South African Railways & Harbours.

One yard, if large enough, should suffice.

New South Wales Government Railways.

A common yard should be used.

North Western Railway, India.

A common yard should be used by all railways.

Federated Malay States Railways.

If Clearing House arrangements are good and common user of wagons in force, one yard is preferable. By an amicable agreement between the different railways the serving of the docks and quays is more economical.

New York Central Lines.

This depends upon the circumstances at each port. The port of New York lends itself to separate yard facilities.

Pennsylvania Railroad Company.

For general traffic : A separate yard for each railway.

For coal traffic : A separate yard for each railway unless special conditions make a common yard the most efficient and economical arrangement.

At New york separate accommodation for each railway is preferred owing to their scattered locations.

Baltimore & Ohio Railroad.

If the marine facilities are open to all railroads and served in common, a common yard would probably be more economical and might permit better handling of traffic.

Reading Company.

A common yard is prefered on account of economies in all directions.

Buenos Ayres Great Southern Railway.

If easy access can be provided for all railways the provision of a common yard appears to be preferable.

Buenos Ayres & Pacific Railway.

One common yard is preferable, provided a uniform system of working can be adopted.

Railway Bureau, Government General of Chosen.

A common yard would be preferred.

QUESTION 4.

In what respects do these yards differ from inland yards?

London and North Eastern Railway.

They are similar to inland terminal yards.

London Midland and Scottish Railway.

There is no essential difference, but it is generally necessary to provide considerably more storage accommodation in a yard serving a port.

Great Western Railway (Great Britain).

No difference.

Canadian National Railways and Canadian Pacific Railway.

No structural difference.

South African Railways and Harbours.

Traffic is continually on the move in inland yards, whereas port traffic has arrived at its destination and is finally disposed of.

North Western Railway, India.

Due to the large number of categories into which shipment wagons have to be sorted, necessitating a number of sorting yards. The supply of wagons to steamers requires special treatment.

Federated Malay States Railways.

Ports are usually at a terminal. The question of routing for traffic passing through does not arise, neither do delays to traffic passing « through ».

New York Central Lines.

Inland yards do not require storage tracks as the traffic moves concurrently through them. In export terminal yards the movement of traffic depends upon the arrival and departure of ships and lighterage conditions which sometimes necessitates storage in cars or on piers.

Pennsylvania Railroad Company.

For general traffic :

There is no essential difference. Holding capacity is important in water front facilities.

For coal traffic :

Yards are designed for maximum storage capacity and for a large number of classifications rather than for continuous movements.

Port of New York.

Terminals at tide water differ very materially from inland yards. Inland yards are almost exclusively for receiving, classification and forwarding from one section of the country to another, while terminal yards are used for the final placing and unloading of cars to ground storage; to lighters, and for transfer to various connections and piers, and vice versa.

Baltimore and Ohio Railroad.

Freight tariffs in the U.S.A. permit certain export shipments to be held in storage on cars at the port. This requirement constitutes the principal difference between port and inland yards. The lay-out of the yards at the port is largely influenced by the shape and size of the area available.

Norfolk and Western Railway.

There is no difference.

Reading Company.

The port yard should give a direct one way movement to the point of delivery to vessels.

Buenos Ayres Great Southern Railway.

There is no substantial difference.

Buenos Ayres and Pacific Railway.

In that the traffic handled emanates from and proceeds to one terminal point and that the classification is varied.

Railway Bureau, Government General of Chosen.

As the direction of traffic at a port is generally definite, it is not considered necessary to sub-divide the concentration yard as is the case at inland yards.

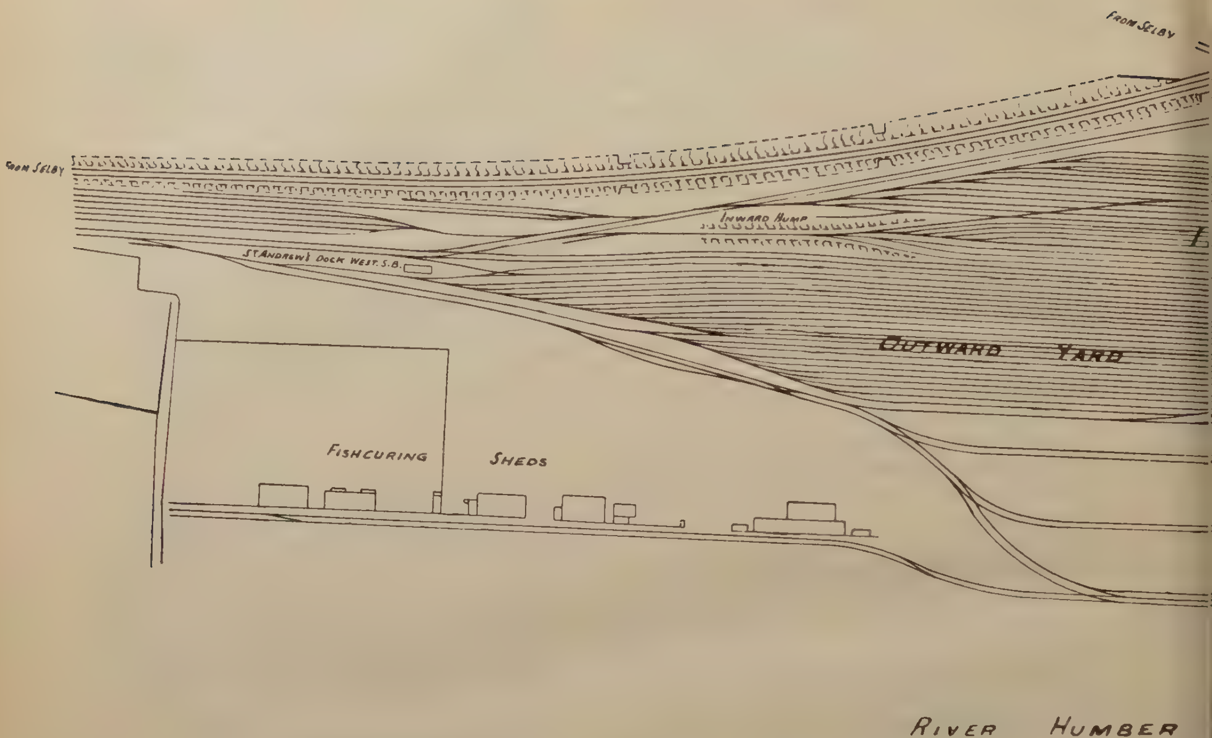


Fig. 3. — Outward and inward goods yards at Hull (Dai

QUESTION 5.

If the existing arrangement had to be reconstructed what arrangement would you adopt, and what essential alterations would you make, and why?

London and North Eastern Railway.

Where there is room the yards not so constructed would be made open ended and reception lines so arranged that wagons could be pushed direct from them into the sorting sidings, and be taken from the latter at the other end.

London Midland and Scottish Railway.

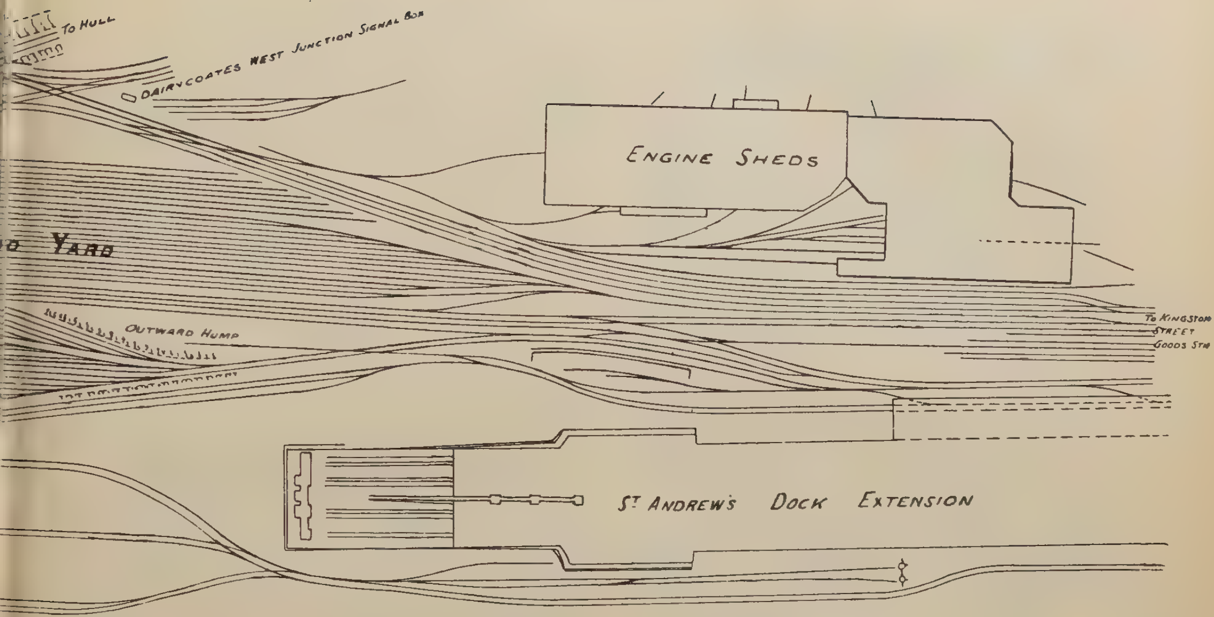
At Speke yard the import marshalling sidings and the port reception sidings are not long enough to hold the maximum main line train loads and a large number of short sidings not exceeding 40 wagon lengths are preferred to a number of long sidings.

Great Western Railway (Great Britain).

Reconstruction at Cardiff docks would mean the elimination of many works, buildings, etc., when it might be possible to improve the lay-out of the yards. The governing factor is the location of the dock water spaces.

Southern Railway (Great Britain).

The present arrangement at Southampton would be maintained.



— London & North Eastern Railway, North Eastern Area.

Canadian National Railways and Canadian Pacific Railway.

Reconstruction at Montreal will be along the line of adequate provision for future extension.

South African Railways and Harbours.

At Durban the provision of three sets of running rails on the water side of the wharf sheds would be considered, to enable landing, shipping and coaling to be undertaken simultaneously and without interruption.

At Table Bay improvements could be effected by reconstruction, e.g. the provision of separate yards for outwards and inwards traffic.

Sudan Government Railways and Steamers.

There is a new lay-out in course of construction at Port Sudan which cannot be criticised until experience has been gained.

New South Wales Government Railways and Tramways.

No essential alterations would be made at Sydney.

North Western Railway, India.

The export and import yards at Karachi should have been situated further East so that traffic to and from the wharves, could pass direct from the export

yard to the wharves, and from the wharves direct to the import yard. The present arrangement necessitates conflicting and uneconomical traffic movements.

The storage platforms have generally only one service line for both loading and unloading. All movements from the platforms to the wharves cross the main service lines. A system of country and port elevators for grain would probably be more economical. The Railway and the Port should also be under one management.

Madras and Southern Mahratta Railway.

Re-arrangement is in progress at Vasco. yard and Mormugao harbour. The breakink up of trains and the storing of manganese will be concentrated at Vasco. and the shed accomodation concentrated at Mormugao.

Federated Malay States Railways.

It would be preferable to have a double ended marshalling yard at the outward end of Port Sweetenham.

New York Central Lines.

At New York City Harbour no material changes would be made. Present arrangement is satisfactory.

Pennsylvania Railroad.

At Philadelphia :

It would be desirable to build the receiving tracks as a separate yard unit to facilitate classifying cars by poling or gravity.

At Sandusky :

The general arrangement is satisfactory, but an effort would be made to provide more storage capacity and a greater number of classifications. The storage yard would be located as near the docks as possible.

Baltimore & Ohio Railway.

Curtis Bay is of recent design and no considerable change would be made.

At Locust Point Yard the arrangement was governed by the location of the piers with respect to the area available for yard purposes, and unless the existing conditions were materially changed only alterations in minor details would be made.

Norfolk & Western Railway.

The existing arrangements are satisfactory.

Reading Company.

The tracks at Port Reading would be shortened and additional lead tracks provided to and from the yard, with more crossovers and no dead ended tracks. This would facilitate operations materially.

Buenos Ayres Great Southern Railway.

At Ingeniero White Port the existing arrangements are satisfactory.

Buenos Ayres and Pacific Railway.

Would provide more accommodation at Madero port for the marshalling of all traffic consigned to the port at the point of connection in order to avoid delay to traffic at outside yards.

Railway Bureau, Government General of Chosen.

The yards at Port Dairen will be enlarged as traffic grows. At Fusan Harbour an independent concentration yard may be provided.

South Manchuria Railway.

Arrangements at port of Dairen are under investigation. The chief desiderata are the enlargement of the yard and the provision of accommodation for long trains.

QUESTION 6.

a) *Please describe in succession the working of traffic from its arrival in train loads up to the placing of the wagons in position for leading to the quay.*

Are wagons arriving at the port marshalled to dock or quay, or to sections of the quay, or to ship's berth, or to hatchway?

If not, what are the operations?

b) *Particularly are there marshalling sidings near the quays?*

If so, what marshalling is carried out there?

Please give a plan of such sidings, shewing the lay-out.

London and North Eastern Railway.

Leith :

a) Full train loads of coal are run into one of the mineral sidings, and are drawn back and shunted. The different classes of coal for each ship are placed in separate sidings ready to be run to the coal hoists on request.

Mixed goods and mineral trains run to the South yard and are shunted : shipment coal is brought to the mineral yard. Shipment goods traffic is taken to the sidings allocated for this purpose. The wagons are marshalled in the yard for the respective ships berths. Traffic arriving before a vessel is berthed, is marshalled for the shed alongside the berth and unloaded.

b) No.

See plan (fig. 2).

Hull, King George Dock :

a) Goods and mineral traffic is led to the respective concentration yards at some distance from the dock where it is sorted for the various docks.

b) King George dock traffic is worked to sorting sidings at the dock and sorted there into quay and ship order.

See plan (fig. 4).

Immingham :

a) Mineral trains are received in the reception sidings and shunted into storage sidings according to colliery or exporter; thence drawn to high level serving roads and propelled to gravity roads leading to the hoists; thence by gravity to the shipping appliances.

The empty wagons return by gravity to empty sidings; are then removed to empty marshalling yard and made up into train loads for collieries.

Goods wagons are sorted at the concentration yard to ship and worked to the berths by steam locomotives.

See plan (fig. 6).

Parkeston Quay :

b) Wagons are sorted into ship order at the concentration yard near the quay and worked direct to the ships side.

The bulk of the traffic is imported.

See plan (fig. 7).

London Midland and Scottish Railway.

Garston :

a) 95 % of the export traffic is coal. Wagons in Speke down reception sidings are split up into ship order and transferred to the coal storage sidings till orders are received to work them to the coal tips.

b) No, wagons are worked direct from Speke sidings to the coal tips full, and back again when empty.

See plan of Garston (fig. 9).

Great Western Railway (Great Britain).

Cardiff :

a) Trains are run direct into the yards, from which point the wagons are taken to the quays as required.

b) Yes, and the wagons are marshalled there in the order required by the ship.

See plan of Cardiff (fig. 11).

Fig. 4. — King George Dock and Salt End Jetties at

Southern Railway (Great Britain).

Southampton :

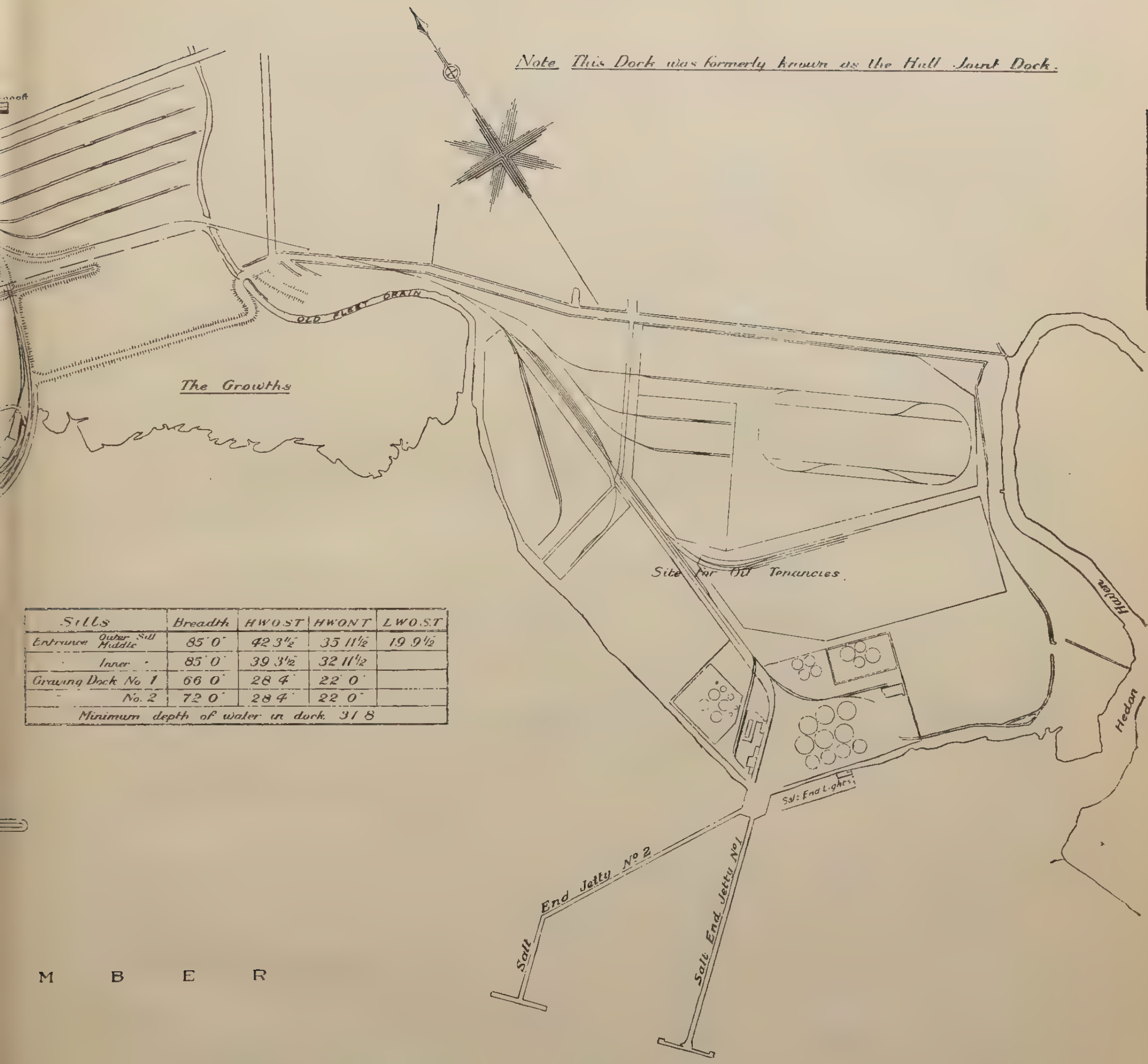
a) Trains are sorted on arrival by dock shunting engines and the wagons worked to the respective berths at which the vessels are lying.

See plan of Southampton (fig. 15).

Canadian National Railways and Canadian Pacific Railway.

Montreal :

a) Cars are tagged and classified. Notices are sent to interested parties, the cars being held for orders. When orders



Sills	Breadth	HWOST	HWONT	LWOST
Entrance Outer Sill Middle	85' 0"	42 3½"	35 11½	19 9½
" Inner "	85' 0"	39 3½"	32 11½	
Graving Dock No 1	66 0"	28 4"	22' 0"	
" No. 2	72 0"	28 4"	22 0"	
Minimum depth of water in dock 31 8				

ndon & North Eastern Railway, North Eastern Area.

received cars are marshalled into switching cuts for delivery to the Port Authority yard. The Port Authority switches the cars to elevators or sheds, as the case may be.

Marshalling in the Railway Company's yards classifies the cars for delivery to elevators, or to sections of the harbour : the Port Authority does the remainder of the work.

Gold Coast Government Railways.

Port Sekondi :

a) Cars removed by shunting engines

Figs. 5-A to 5-L. — Particulars of cranes, King George Dock, Hull.
London and North Eastern Railway.

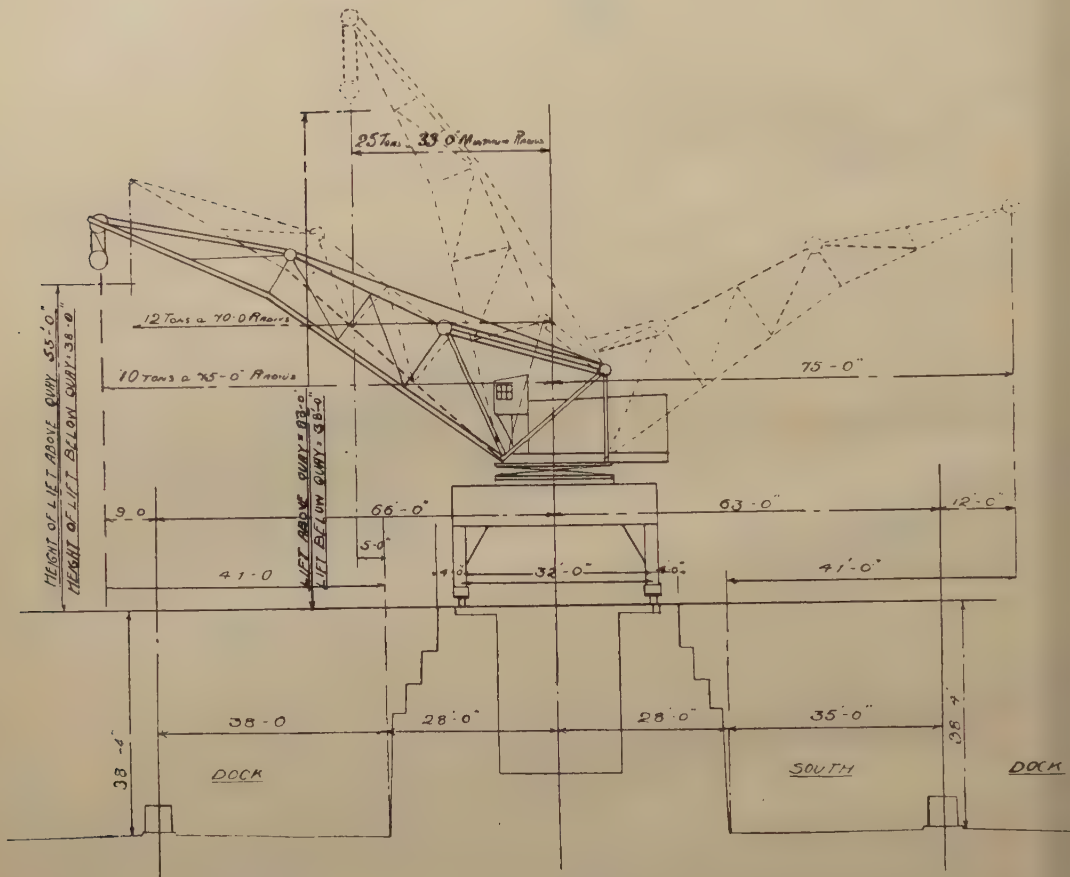


Fig. 5-A. — 25-ton electric graving dock crane, King George Dock, Hull.

Speeds and motors.

Hoisting: Slow gear, 25 tons at 20 feet per minute.
Fast gear, 6 tons at 80 feet per minute.
Motor: 50 B.H.P. at 500 revolutions per minute.

Slewing: 25 tons at 1 revolution in 2 minutes.
Motor: 12 B.H.P. at 500 revolutions per minute.

Travelling: 25 tons at 50-60 feet per minute.
Motor: 30 B.H.P. at 650 revolutions per minute.

Derricking: About 8 ft. 9 in. per minute.
Motor: 30 B.H.P. at 650 revolutions per minute.

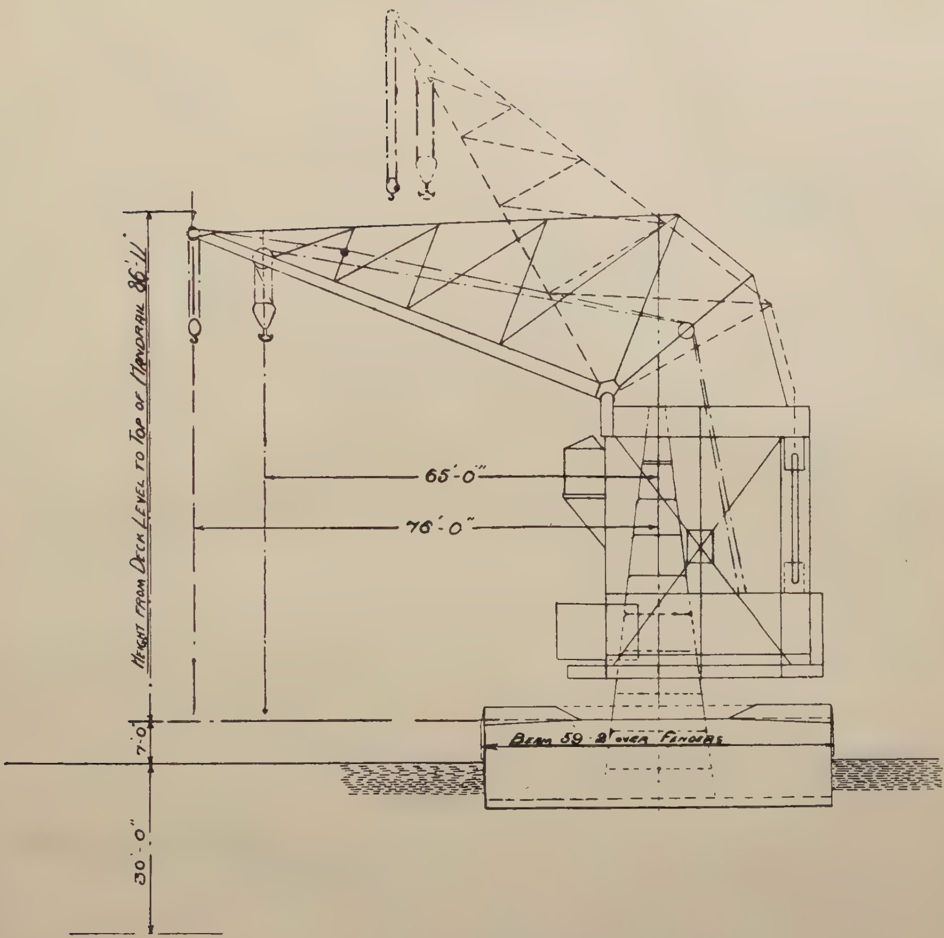


Fig. 5-B. — 80-ton floating crane, King George Dock, Hull.

Reference.

Load.	Radius.	Feet per minute.
80 tons	65 feet	5
40 —	65 —	10
10 —	46 —	40

Luffing speed at hook 5
Revolving speed at hook (max.) 200
Hook to lift above water level, 70 feet.
Hook to lower below water level, 30 feet.
The crane will remain practically level athwart ships while lifting loads up to 80 tons at a radius of 65 feet.

Motors.

Main generator:	105 kw.,	220 volts,	250 revs.	per minute.
Lighting generator:	4.5 —	220 —	800	—
Main lifting motor:	70 B.H.P.,	220 —	500	—
Auxiliary motor:	50 —	220 —	700	—
Derricking motor:	50 —	220 —	700	—
Slewing motor.	70 —	220 —	700	—
Oil pump motor:	15 —	220 —	590	—
Counter wt. motor	5 —	220 —	1 260	—

Lighting generator driven by paraffin gas engine.

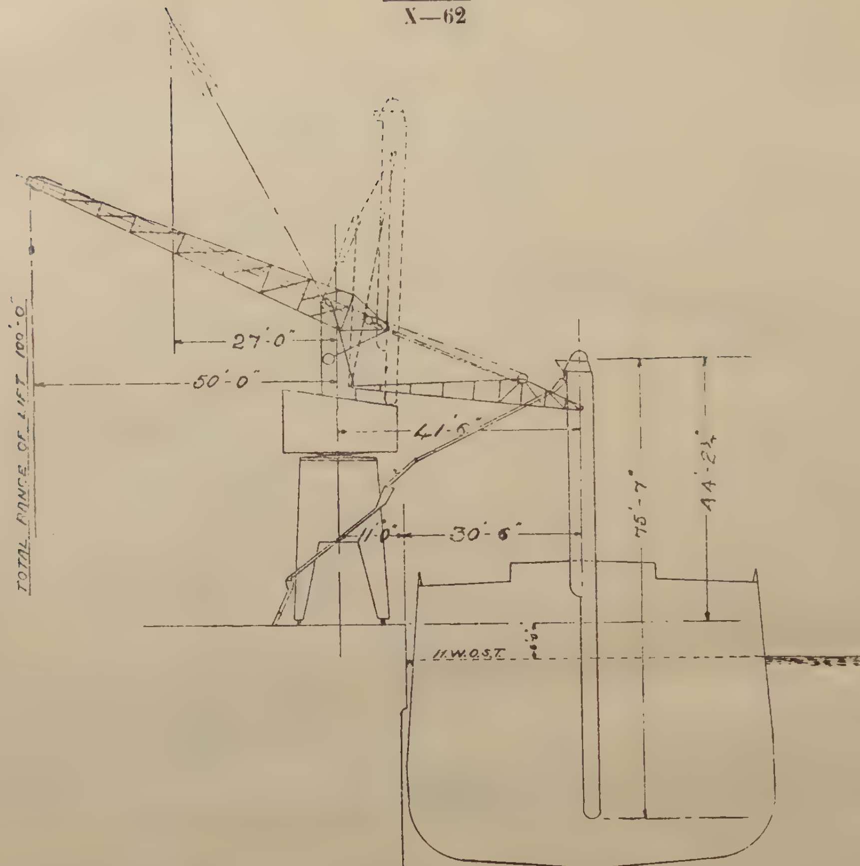


Fig. 5-C. — 10-ton electric crane with grain elevators, King George Dock, Hull.

Speeds and motors.

Speeds.

Hoisting :	10 tons at 50 feet per minute
Slewing :	Maximum at 300 feet per minute.
Luffing :	10 tons at 100 feet per minute.
Travelling :	10 — 30 —

Motors.

Hoisting :	55	B.H.P.,	540 revs.	per minute,	440	volts.
Slewing :	12 ½	—	500	—	440	—
Luffing :	15	—	500	—	440	—
Travelling :	15	—	500	—	440	—

Grain elevator motor.

24 B.H.P., 750 revs. per minute, 440 volts.

from reception yard to marshalling yard and marshalled there for position at various points in harbour.

South African Railways and Harbours.

Durban :

a) Train loads are sorted at concentration yard and despatched to the particular section of the harbour where required. The marshalling to dock or quay is undertaken at the port yard.

b) Yes, the trucks are shunted out for the various sheds or ships.

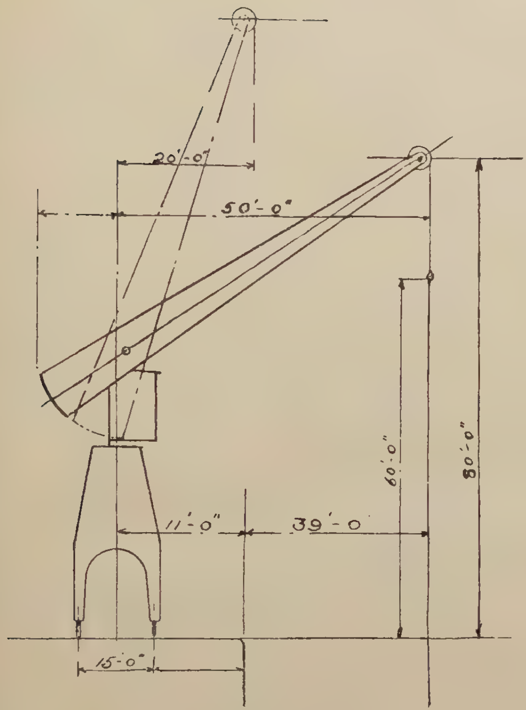


Fig. 5-D. — 3-ton electric crane, King George Dock, Hull.

Speeds and motors.

Hoisting:	Full load, 150	feet per minute,	45 H.P. at 300	revs. per m.
Luffing:	150	—	8 H.P. at 500	—
Slewing:	Maximum, 400	—	5 H.P. at 600	
Travelling:	30	—	8 H.P. at 500	—

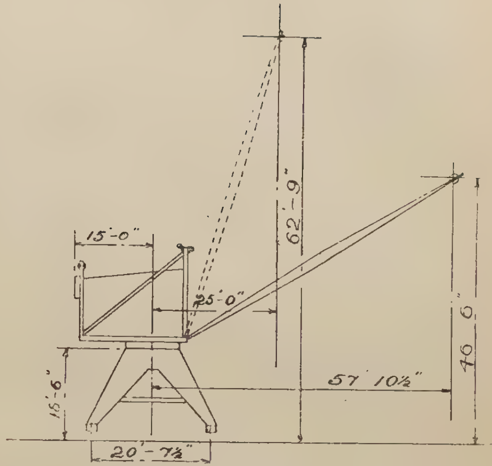


Fig. 5-E. — 1/2-ton electric warehouse crane, King George Dock, Hull.

Speeds and motors.

Speeds.

Hoisting:	1 ½ tons at	250	feet per minute.
Slewing:	Maximum at	450	—
Luffing:	1 ½ tons at	200	—
Travelling:	1 ½ —	50	—

Motors.

Hoisting:	35	B.P.H.,	400	revs. per m.,	440	volts.
Slewing:	6	—	500	—	440	
Luffing:	6	—	500	—	440	—
Travelling:	6	—	500	—	440	—

Table Bay Harbour :

a) All inward traffic, such as coal, grain, or general, sorted at a group of sidings at the entrance to the docks, and then distributed to coal sites, grain stores, or quays.

b) Only grain in bulk is marshalled on entering the docks.

See plan (fig. 16).

Sudan Government Railways & Steamers.

Port Sudan :

a) Trains are sorted for private warehouses, Port Authority warehouse, or stacking ground, or for ship.

New South Wales Government Railways.

Sydney :

a) Trains received on reception sidings, engines released, and trucks shunted by gravitation to the classification yard and propelled to points required at the port for shipment. Empty trucks are shunted to empty road by capstans and subsequently cleared to general yard by shunting engines.

b) Wagons are marshalled after arrival at the port for different sections and for various shipping consignees.

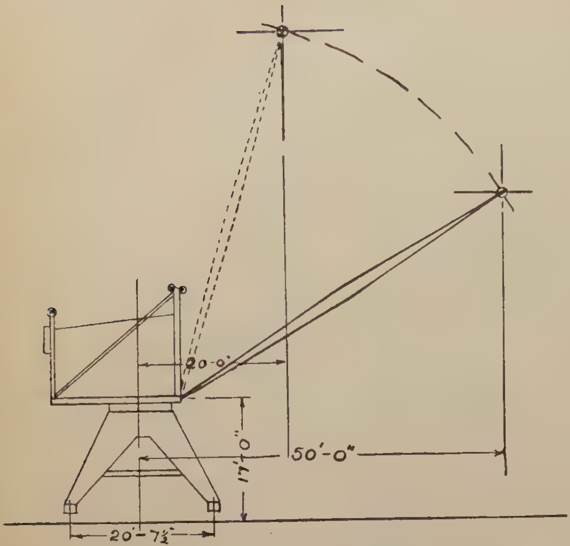


Fig. 5-F. — Electric roof cranes to lift 1 $^1/_2$ tons, King George Dock, Hull.

Speeds and motors.

Speeds.

Hoisting:	1 ½	tons at	250	feet per minute.	
Slewing:	1 ½	—	450	—	
Luffing:	1 ½	—	150	— horizontally.	
Travelling:	1 ½	—	50	feet per minute.	

Motors.

Hoisting:	38 H.P.	at	675	revs. per minute.
Slewing:	5 H.P.	at	650	—
Luffing:	5 H.P.	at	600	—
Travelling:	6 H.P.	at	600	—

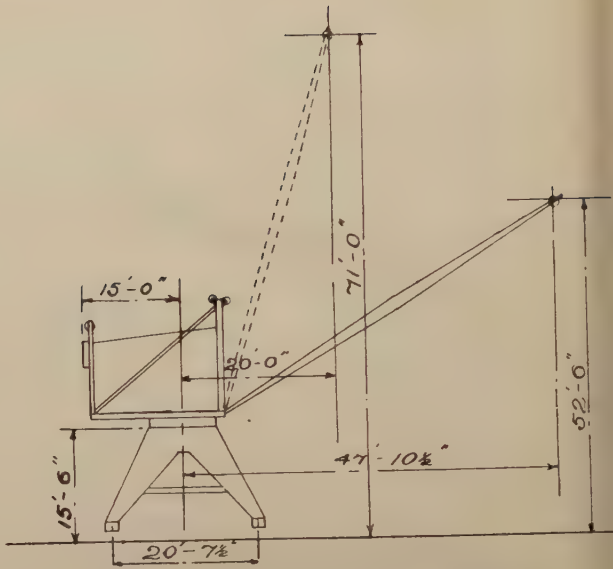


Fig. 5-G. — 1 $^1/_2$-ton electric warehouse crane, King George Dock, Hull.

Speeds and motors.

Speeds.

Motors.

Hoisting:	1 ½ tons at	250	feet per minute.
Slewing:	Maximum at	450	—
Luffing:	1 ½ tons at	200	—
Travelling:	1 ½ tons at	50	—

Hoisting:	35	B.H.P.,	400	revs. per m.,	440	volts.
Slewing:	6	—	500	—	440	—
Luffing:	6	—	500	—	400	—
Travelling:	6	—	500	—	440	—

North Western Railway, India.

Karachi :

a) The Port Trust Railway is worked by the North Western Railway along with its own railway terminal traffic and traffic for private sidings and Government sidings 6 miles outside Karachi.

Export traffic, private siding and Karachi City traffic is worked to the port trust yards. Trains from the reception yard are sorted over a hump with 19 tracks. There are well over 200 destinations, and wagons require additional sorting. Most of the cars of export traffic are unloaded on open platforms leased to various exporters and merchants where the traffic is sorted, stored, and finally reloaded into cars for shipping.

Import traffic is loaded direct into cars and removed about 3 miles to sheds, bonded warehouses, or stacking yards, where custom dues are collected and merchants take delivery, removing their goods to their godowns or to the railway outward goods yard by road.

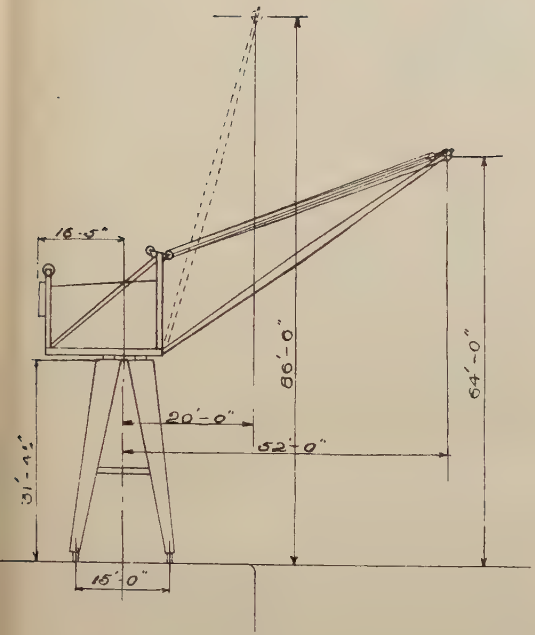


Fig. 5-H. — 7-ton electric crane,
King George Dock, Hull.

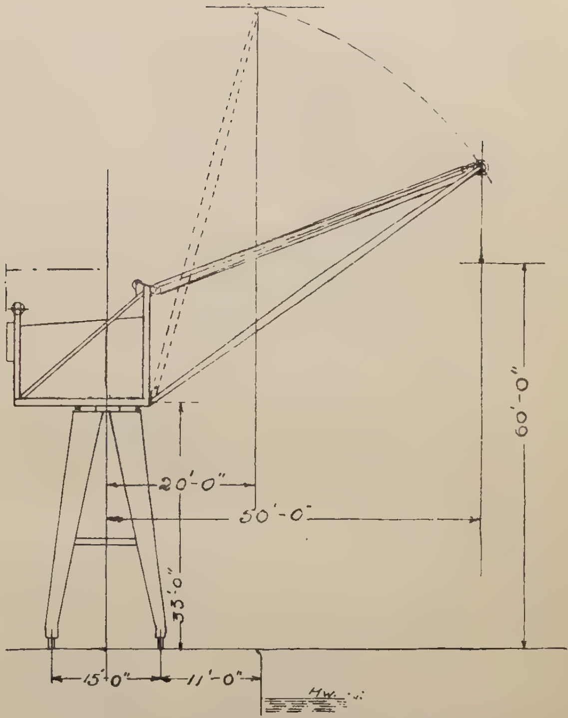


Fig. 5-I. — Electric crane to lift 3 tons,
King George Dock, Hull.

Speeds and motors.

:	7	tons at 60 feet per min.,		45 B.H.P. at		550 revs. per min.	
:	3 ½	—	120	—	45	—	550 —
	7	—	100	—	10	—	600 —
g :	7	—	30	—	8	—	600 —
	7	tons at					
max. radius)			300	—	10	—	600 —

Speeds and motors.

Speeds.

Hoisting :	3	tons at 150 feet per minute.	
Hoisting :	1 ½	tons at 250	—
Slewing :	3	tons at 400	—
Luffing :	3	tons at 150	—
Travelling :	3	tons at 30	—

Motors.

Hoisting :	45 B.H.P. at	550 revs. per minute.		
Slewing :	6	—	600	—
Luffing :	6	—	600	—
Travelling :	6	—	600	—

Full car loads can also be booked direct from the import sheds and from the Kiamari export yard.

Import traffic and surplus empty wagons are collected at the City Station from which trains depart inland.

b) Traffics reloaded in the export yard are sorted for steamers and for hatchways on grids near the wharf serving one or more berths.

From these grids they are placed on lines running the whole length of the East wharf, turn-outs being provided for each berth.

Madras and Southern Mahratta Railway.

Mormugao Harbour :

a) Trains arrive at Vasco, and are divided into manganese, groundnuts, and oil cake, and coastal traffic.

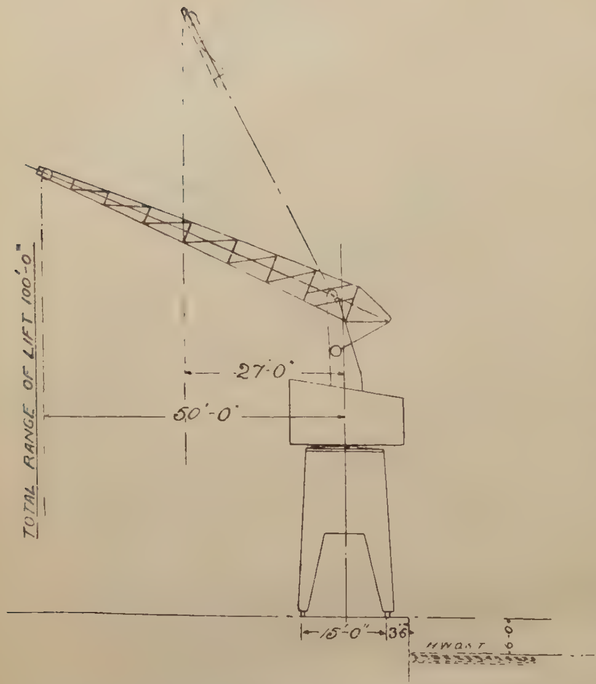


Fig. 5-J. — 10-ton electric crane without grain elevator, King George Dock, Hull.

Speed.

Hoisting :	10 tons at	50 feet per minute.	
Slewing :	Maximum at 300	—	
Luffing :	10 tons at	100	—
Travelling :	10 —	30	—

Motors.

Hoisting :	55	B.H.P.,	540	revs. per m.,	440	volts.
Slewing :	12 ½	—	500	—	440	—
Luffing :	15	—	500	—	440	—
Travelling :	15	—	500	—	440	—

Manganese is discharged at Vasco. to dumps.

Wagons with groundnuts and oil cake are taken to the harbour and discharged to shed for reconditioning.

Coastal traffic is taken to the Harbour and discharged in a shed close to the quay, and the traffic is man handled direct from shed to slings for shipment.

The manganese, oil cake, and ground nuts require to be reloaded into cars and taken to the quay.

b) There are a few sorting sidings near the quay where wagons are marshalled prior to being placed alongside the ships.

Ceylon Government Railway.

Colombo :

a) Export traffic arrives on various trains; the greater portion is dealt with at Lakeside and taken by barges to the Harbour and loaded direct to the steamer. Traffic sent to the port is transferred to the Port Commissioners at Bloemendhal who deal with traffic in their own area.

Federated Malay States Railways.

Port Sweetenham :

a) All inward trains are taken to reception sidings; from there the wagons are shunted into the marshalling sidings for various wharves and godowns.

Wagons are not marshalled before arrival at the port.

New York Central Lines.

City of New York Harbour :

a) On arrival shunting engines distribute the cars according to classification or pier assignment; thence they are shunted to piers or quays for unloading to lighters going to steamship docks or ships. When the delivery to ship is of indefinite date traffic is unloaded on the pier for storage and the cars released.

b) Marshallings sidings are adjacent to the piers and cars are shunted from classification track to these sidings before being placed on piers for delivery.

Pennsylvania Railroad Company.

a) *At Philadelphia :*

The traffic is classified and moved to small holding yards advantageously

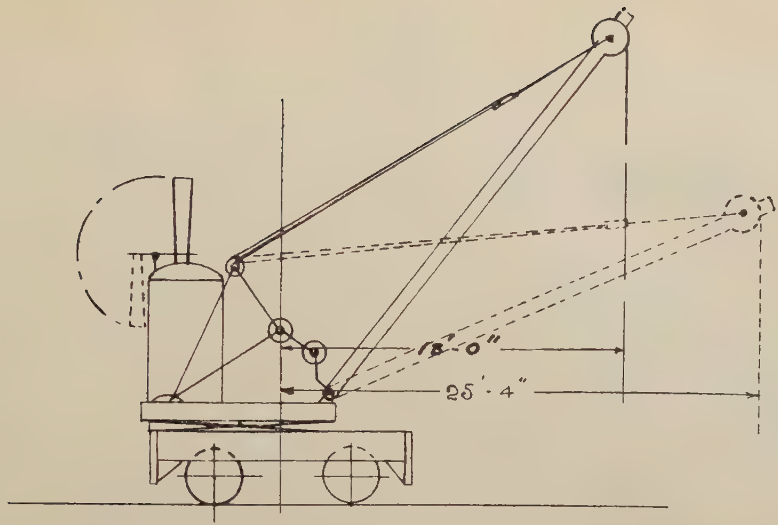


Fig. 5-K. — Portable steam crane, King George Dock, Hull.
Lifts 5 tons at 18 feet and 2 1/2 tons at 25 ft. 4 in.

Speeds

Traversing speed — fast : 6 miles per hour.
— — slow : 3 —
Will draw 6 loaded wagons of coal, 10 unloaded.
Lifting speed with load of 5 tons : 50 feet per minute.
Revolving speed ; once round in 25 seconds.

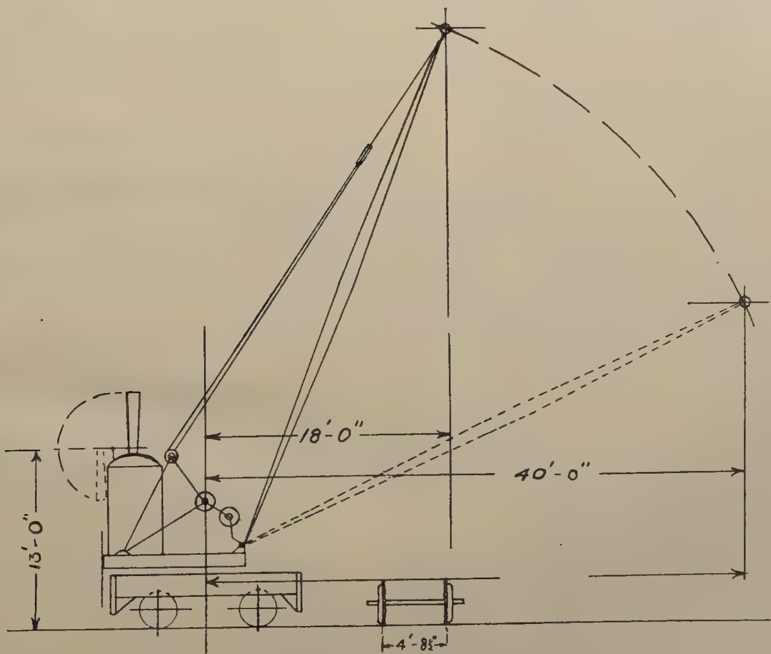


Fig. 5-L. — Portable steam crane, King George Dock, Hull.
Lifts 5 tons at 18- foot radius and 15 cwts at 40- foot radius. For short jib see fig. 5-K.

Speeds

Traversing speed — fast : 6 miles per hour.
— — slow : 3 —
Will draw six loaded wagons of coal, 10 unloaded.
Lifting speed with load of 5 tons : 50 feet per minute.
Revolving speed ; once round in 25 seconds.

located for movement to the piers. When ordered for placement the cars are moved to the ships berth and spotted to hatchways.

At Sandusky :

From the receiving yard trains are shunted over the hump and separated for each consignee in the classification yard. They are then taken to the store yard to await ship.

b) No shunting or classifying is done at the docks.

Port of New York :

East bound traffic goes first to the receiving yard and is classified into :

Float yards : each track in the yard being of the same capacity as the car floats, or

Lighterage yards : where cars are held subject to orders for lightering or unloading to ground or covered pier storage.

Baltimore & Ohio Railroad.

Port of Baltimore :

a) Arriving trains are pulled into the receiving tracks at Locust Point terminal. Inbound classification tracks are used for breaking up the train; the cars ordered for immediate placing are moved to the proper piers, and cars awaiting orders are placed on the storage tracks.

Norfolk and Western Railway.

Lambert's Point and Norfolk Harbour:

a) On the arrival « side tags » are attached to the cars shewing where they are to go; cars are then shunted to the tracks that lead to the quays or coal piers.

b) Cars are taken to tracks leading to the quay or pier and shunted to the quay as needed.

Reading Company.

Port Reading :

a) Train loads are separated and shunted to various tracks by locomotives, according to kinds and grades of commodity. When orders are received cars are assembled by locomotives and placed on the pier for delivery.

Buenos Ayres Great Southern Railway.

Ingeniero White Port :

a) On arrival the wagons are weighed, if this has not already been done, marshalled in vessel order, and hauled to the section of quay where ships are berthed. The wagons are hauled to the section by shunting engine and placed in front of hatchways by capstans.

b) There are mashallling sidings near the quays for classifying traffic for export, when this cannot be done at the concentration yard. They are also used for forming trips of import traffic to the fiscal deposits.

Buenos Ayres and Pacific Railway.

Madero Port at Buenos Ayres :

a) Trains arrive marshalled in dock order. Consignments for elevators, ships, sheds, etc. are grouped together.

b) Yes, for classification of empties for return to each proprietor Company.

Japanese Government Railways.

a) Upon arrival of the train the cars are sorted according to destination and contents and taken to the quay lines.

See plan of Kobe (fig. 21).

Railway Bureau, Government General of Chosen.

Port of Dairen :

a) Cars are sorted according to destination and contents. They are then

taken to the quay lines and unloaded into warehouses, or on to platforms for despatch. It is not usual for traffic to be handled direct between car and steamer.

South Manchuria Railway.

Port of Dairen :

Arriving cars are marshalled at the concentration yard and led to unloading sidings for storing in railway warehouses or direct to sections of the quay, and the traffic is removed to the ships either by small locomotives, tractors, carriages, electric tractors, or carts.

QUESTION 7.

When empty wagons are released from the port how are they dealt with?

Do they pass directly to some other point, or from one section to another; or do they pas through the concentration yard at which the wagons coming from inland arrive?

London and North Eastern Railway.

Discharged goods and mineral wagons are either re-loaded or taken to the concentration yard, or worked to inland destinations direct.

London Midland & Scottish Railway.

Empty wagons are worked from the coal tips to Speke sidings and despatched thence in full train loads to the collieries. Coal and coke shipment end-door wagons are despatched in train loads as ordered by the Rolling Stock Distribution Department.

Great Western Railway (Great Britain).

Discharged wagons are moved to sidings, sorted, and placed in readiness for main line engines and depart through the concentration yard.

Southern Railway (Great Britain).

Wagons discharged, plus others, are used for outward loading.

Canadian National Railways and Canadian Pacific Railway.

Empties are marshalled by the Port Authority and returned to the respective railways from which the loads were received. Ordinarily empties are returned to the interchange point at which they were received loaded, but sometimes by special orders they are sent to other points.

South African Railways and Harbours.

At Durban discharged cars pass direct to other loading points at the harbour; the balance go to the concentration yard for despatch inland.

At Table Bay empty cars when not required for loading are disposed of in train loads to inland centres.

Gold Coast Government Railways.

Discharged cars are allocated and moved to points at the harbour for reloading. Surplus cars are returned to the marshalling yards.

Sudan Government Railways & Steamers.

Discharged cars are distributed either for immediate re-loading or are sent away for local transport.

New South Wales Government Railways.

Discharged wagons are cleared by capstans, then transferred by shunting engines to outwards concentration yard and subsequently despatched in train loads.

North Western Railway, India.

Discharged wagons are utilised for imports. When necessary they are worked in train loads inland for re-loading.

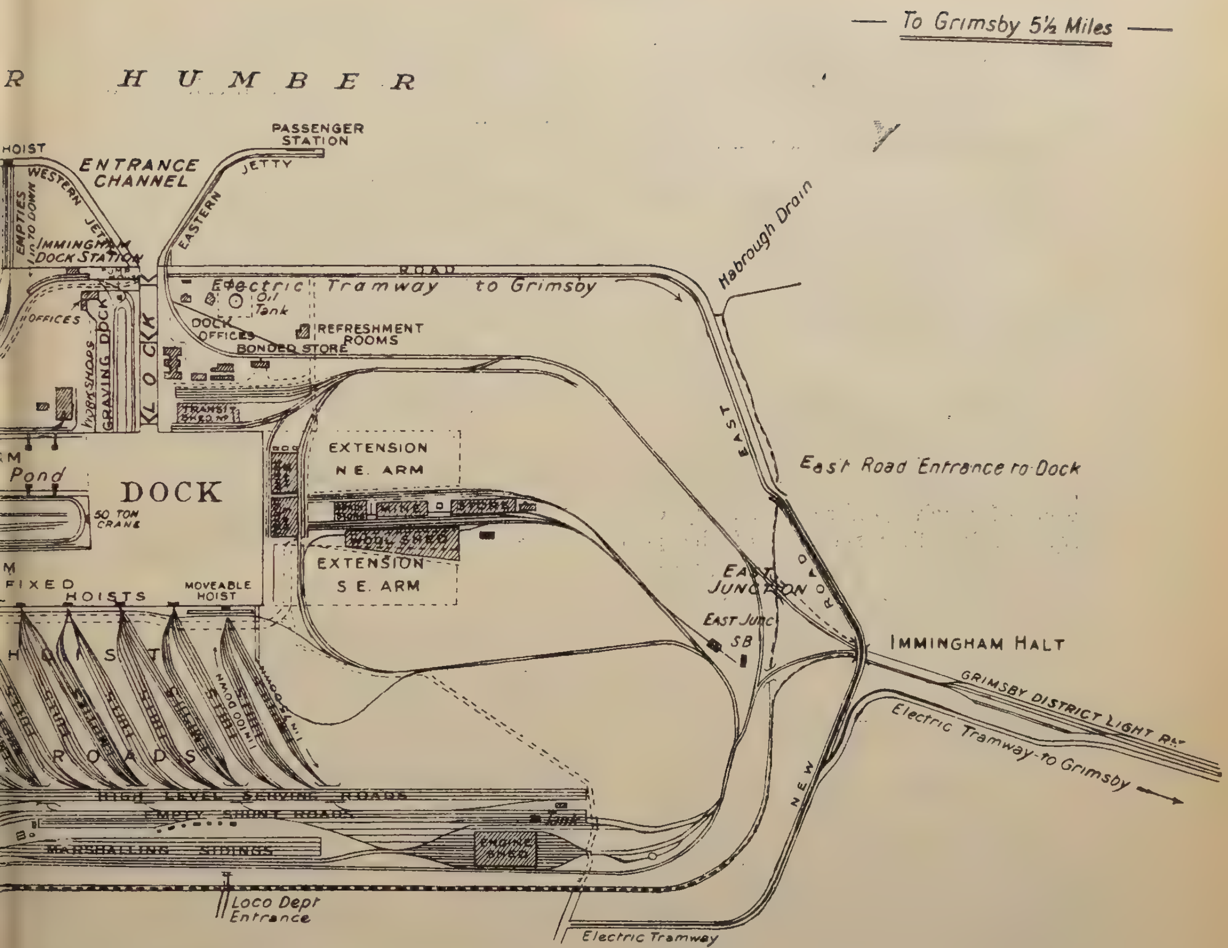
Fig. 6. — Plan of Immingham Dock, J

Madras & Southern Mahratta Railway.

Empty wagons are despatched from the port immediately, unless they are utilised for import traffic.

Ceylon Government Railway.

Discharged cars are all required for re-loading.



ARISH OF IMMINGHAM
AL DISTRICT OF GRIMSBY.

Scale: 4.65 inches = 1 mile.

npanys Boundary shewn thus------

28. — London & North Eastern Railway.

Federated Malay States Railways.

All discharged cars are placed at the quay for re-loading.

New York Central Lines.

Discharged cars are placed on marshalling sidings for outward loading at

piers, or are taken direct to outward classification yards and placed on trains for other loading points.

Pennsylvania Railroad Company.

At Sandusky cars pass from the port to the outward classification yard.

At New York discharged cars are moved to the West bound receiving yard, classified, and moved to the West bound departure yard for movement West in trains loads.

Baltimore & Ohio Railroad.

The outward bound classification tracks are used to make up trains composed of discharged cars. Empty cars required in other sections of the port are transferred by switching engines — the remainder are sent inland on trains.

Norfolk and Western Railway.

Discharged cars are shunted from quay to quay for re-loading.

Reading Company.

Discharged cars are assembled in sidings in the concentration yard set apart for this purpose and assembled in trains loads, so that locomotives bringing in loaded cars can readily be used to take away the empty train loads.

Buenos Ayres Great Southern Railway.

Empty wagons are concentrated at a point independent from the concentration yard.

Buenos Ayres & Pacific Railway.

If classification is necessary wagons are taken to sidings adjacent to the quays, thence to reception sidings at connecting points; otherwise direct to reception sidings.

Japanese Government Railways.

At the coaling ports discharged cars are returned direct to the collieries or to a concentating station from which they are distributed.

Railway Bureau, Government General of Chosen.

Discharged cars are reloaded at the quays, surplus empty wagons are removed to sidings until they are required for other purposes.

South Manchuria Railway.

All empty wagons are returned to the concentration yard, thence by train to inland stations or to the imported goods sidings.

QUESTION 8.

Are definite instructions issued that despatches of traffic comprising several wagons from inland towards the port are not to be separated at the point of departure, or during the journey, even if this would result in reducing the loads of certain trains?

London and North Eastern Railway.

No, but consignments are generally forwarded intact.

London Midland & Scottish Railway.

No, shipment coal works through in full train loads.

Great Western Railway (Great Britain).

Despatches comprising several wagons from inland are not separated as a general rule. Reduction of train loads would be avoided as much as possible.

Southern Railway (Great Britain).

No.

Canadian National Railways and Canadian Pacific Railway.

No.

South African Railways and Harbours.

As occasion demands instructions are given for the through transit of traffic to Durban to ensure prompt arrival and shipment by a particular ship. This does not interfere with the load of the train, e.g. bulk grain is conveyed in block loads or part loads to the port.

Block loads conveying fruit, grain, or coal, are seldom separated en route to Table Bay.

Sudan Government Railways.

No, export traffic is generally in through loads.

New South Wales Government Railways.

No, the traffic for shipment is given preference over ordinary traffic to ensure the best possible transit having regard to full train loads being obtained.

North Western Railway, India.

Traffic for the port is segregated at the earliest opportunity in up country yards and run as through loads.

Madras and Southern Mahratta Railway.

No, as practically all traffic is dumped at the port.

Ceylon Government Railway.

Shipment goods are given preference, ordinary traffic being left to allow port traffic to come forward.

Federated Malay States Railways.

No.

New York Central Lines.

Instructions are sometimes issued to this effect, but this does not, as a rule, tend to reduce train loads.

Pennsylvania Railroad.

At Philadelphia :

In certain instances such instructions are issued, but not as a general practice.

At Sandusky :

No such instructions are issued.

At New York :

There are some shipments of more than one car which it is important to keep together throughout their journey, and this is done as far as possible.

Baltimore & Ohio Railroad.

At Brunswick yard, 72 miles inland from Baltimore, all East bound traffic is classified for destinations. At this yard cars destined for Locust Point Terminal are forwarded from Brunswick to Baltimore, either in groups or as a solid train, and are not interfered with en route.

Norfolk and Western Railway.

Not unless definite instructions were given by the sender.

Reading Company.

Full train loads only are assembled and moved to the port except in rare instances.

Buenos Ayres Great Southern Railway.

Wagons consigned to a certain vessel are not separated.

Buenos Ayres & Pacific Railway.

Yes, no reduction in train load occurs.

Japanese Government Railways.

No, but despatches of traffic are kept together as far as possible.

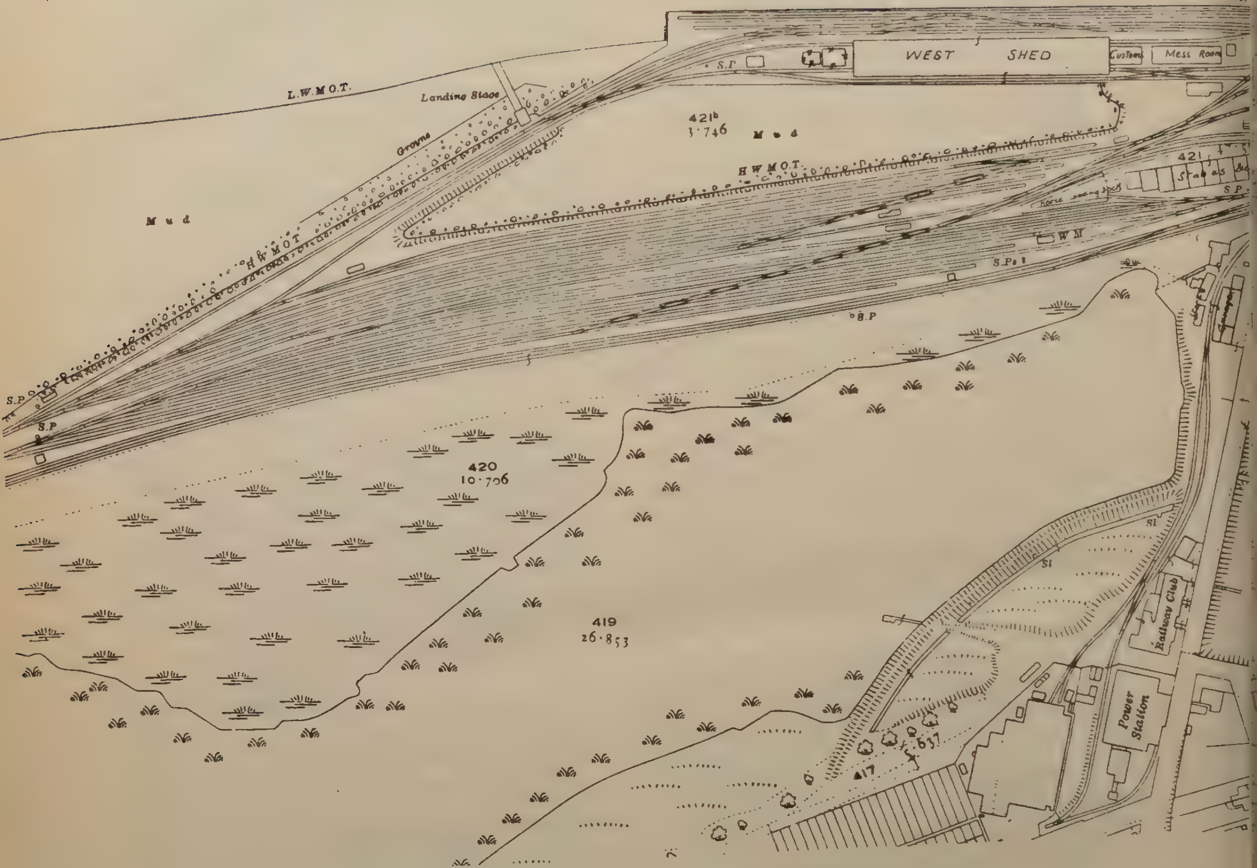


Fig. 7. — Parkeston Quay. –

Railway Bureau, Government General of Chosen.

No.

South Manchuria Railway.

Traffic, as far as possible, is worked in train loads from destination to the port.

PART II.

SECTION I.

General arrangements adopted for serving the quays by railways.

SECTION II.

Loading and unloading appliances.

SECTION I.

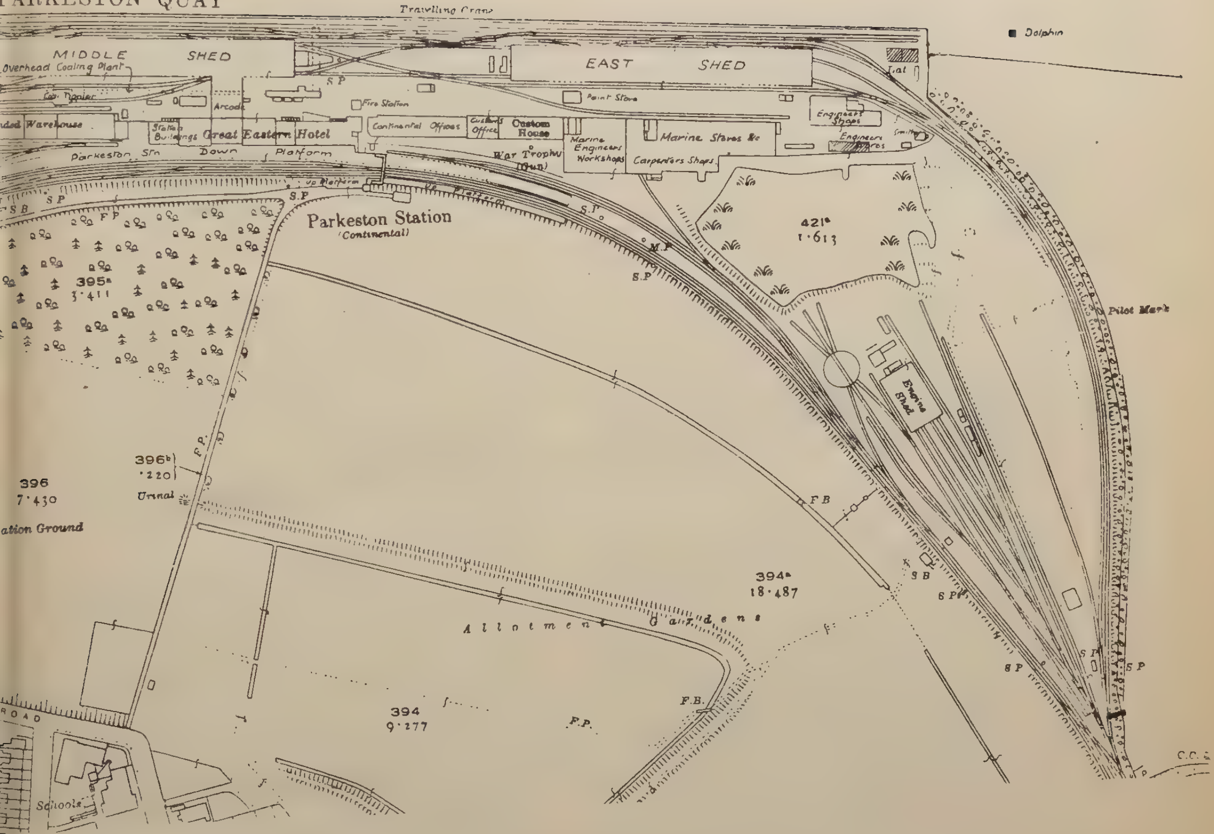
Arrangement of quays.

QUESTION 9.

Please describe upon a plan, 1/5000 th scale if possible, the layout of the quays (jetties, docks, long quays).

Are the quays continuous or indented?

PARKESTON QUAY



North Eastern Railway.

London and North Eastern Railway.

Leith, King George Dock, Immingham, and Parkeston Quay :

Quays are continuous. See plans of above ports (figs. 2, 4, 6, and 7).

London Midland and Scottish Railway.

The quays are continuous. See plan of Garston (fig. 9).

Great Western Railway (Great Britain).

The quays are continuous.

See plan of Cardiff (fig. 11).

Southern Railway (Great Britain).

See plan of Southampton (fig. 15).

South African Railways and Harbours.

The quays at Durban are continuous. See plan of Capetown (fig. 16).

Sudan Government Railways & Steamers.

The quays are continuous.

New South Wales Government Railways.

Piers and jetties are used at Sydney. The quays are continuous at Bullock Island.

North Western Railway, India.

The quays are continuous.

Madras and Southern Mahratta Railway.

The quays are continuous at port Sweetenham.

Ceylon Government Railway.

There are no quays belonging to the Ceylon Government Railway at Colombo except Talai-Mannar Pier, which is 920 feet long, 30 feet wide, with two lines of track in the berth 320 feet long. At the Colombo Port Commission the whole of the traffic to and from ship is handled by barges.

New York Central Lines.

Piers and jetties are in use at New York.

Pennsylvania Railroad.

Piers and jetties are in use at New York, Philadelphia and Sandusky.

Baltimore and Ohio Railway.

Piers are used at Baltimore.

Norfolk and Western Railway.

Lambert's Point, Virginia and Norfolk Harbour consist of a series of piers and there are no continuous quays. The tracks are depressed and the quays are level with the car floors. There are apron tracks on the outside of the sheds for handling open cars.

Buenos Ayres Great Southern Railway.

The quays are continuous.

Japanese Government Railways.

See plan of Kobe (fig. 21).

South Manchuria Railway.

Jetties are in use.

QUESTION 10.

Please indicate the lay-out of the quay lines and the lines behind them; the number; the junctions between them and the approach lines; the lay-out of the cart roads, and the arrangement of the lines serving the sheds and warehouses.

London and North Eastern Railway.

See plans of Leith, King George Dock Hull, Immingham and Parkeston Quay (fig. 2, 4, 6 and 7).

London Midland and Scottish Railway.

There is no road access. See plan of Garston (fig. 9).

Great Western Railway (Great Britain).

See plan of Cardiff (fig. 11).

Southern Railway (Great Britain).

See plan of Southampton (fig. 15).

South African Railways and Harbours.

See plan of Capetown (fig. 16).

Buenos Ayres Great Southern Railway.

There are no cart roads to the quays. The sheds, warehouses, and fiscal deposits are served by privately owned sidings and are within three kilometres of the port.

Japanese Government Railways.

See plan of Kobe (fig. 21).

QUESTION 11.

How are these lines worked? Do you use horses, locomotives, tractors, capstans? Do you use turntables, traversers, switches? Which of these methods do you prefer, and why?

London and North Eastern Railway.

Leith:

Traffic is worked to the quay lines by

steam locomotives, and capstans are used to place wagons in position and withdraw them. At coal hoists capstans are used for placing end door wagons on to the turntables and for turning them; and for placing them in the hoists and for removing them from the hoists to the empty lines.

Hull, King George Dock :

Steam locomotives are used for working general traffic to the quay lines and capstans are used for placing wagons in position and removing them.

At the coaling belts the laden wagons are placed on gravity lines by steam locomotives and are worked by gravity to the discharging point, and from there to the empty sidings.

Wagons are worked to and from the coaling hoists by gravity, and on to and off the hoists by capstans.

Switches.

Immingham :

Traffic is worked to the quay lines by steam locomotives, and capstans are used to place wagons in position and for withdrawing them.

At coaling hoists capstans are used for placing end door wagons on to turntables, and for turning them, and for moving them on to and off the hoists to the empty lines.

Switches are used and a traverser worked by capstan is also used for working wagons from the quayside to adjacent lines.

Parkeston Quay :

Wagons are worked to and from the quay by steam locomotives, and to and from positions alongside the ships, and in to and out of the ships by capstans.

Switches.

The arrangements are entirely satisfactory.

London Midland and Scottish Railway.

The manipulation of wagons in the coal quay berths is by hydraulic capstan.

Switches are used.

Turntables are used on the coal tips in order to get the end door into position for tipping.

The method of working is entirely satisfactory.

Great Western Railway (Great Britain).

Locomotives work the traffic to and from the quays alongside the ships. Capstans or hoists are used, but method adopted depends upon the local lay-out.

Switches are used.

Southern Railway (Great Britain).

By shunting engines and electric tractors.

Switches.

Existing system preferred.

Canadian National Railways and Canadian Pacific Railway.

By steam and electric locomotives. Switches are in general use.

South African Railways and Harbours.

At Durban locomotives are used for placing and withdrawing cars from wharf side. When alongside a steamer, cars are placed in position by electric capstan.

At Table Bay by locomotive power, which is found to be the most satisfactory and expeditious means.

Gold Coast Government Railways.

By locomotives.

Switches.

Sudan Government Railways & Steamers.

By steam shunting locomotives.

Switches only.

Fig. 8. — Diagram of Speke Junctio

New South Wales Government Railways.

By all the means mentioned except horses. Capstans are preferred on account of economy.

North Western Railway, India.

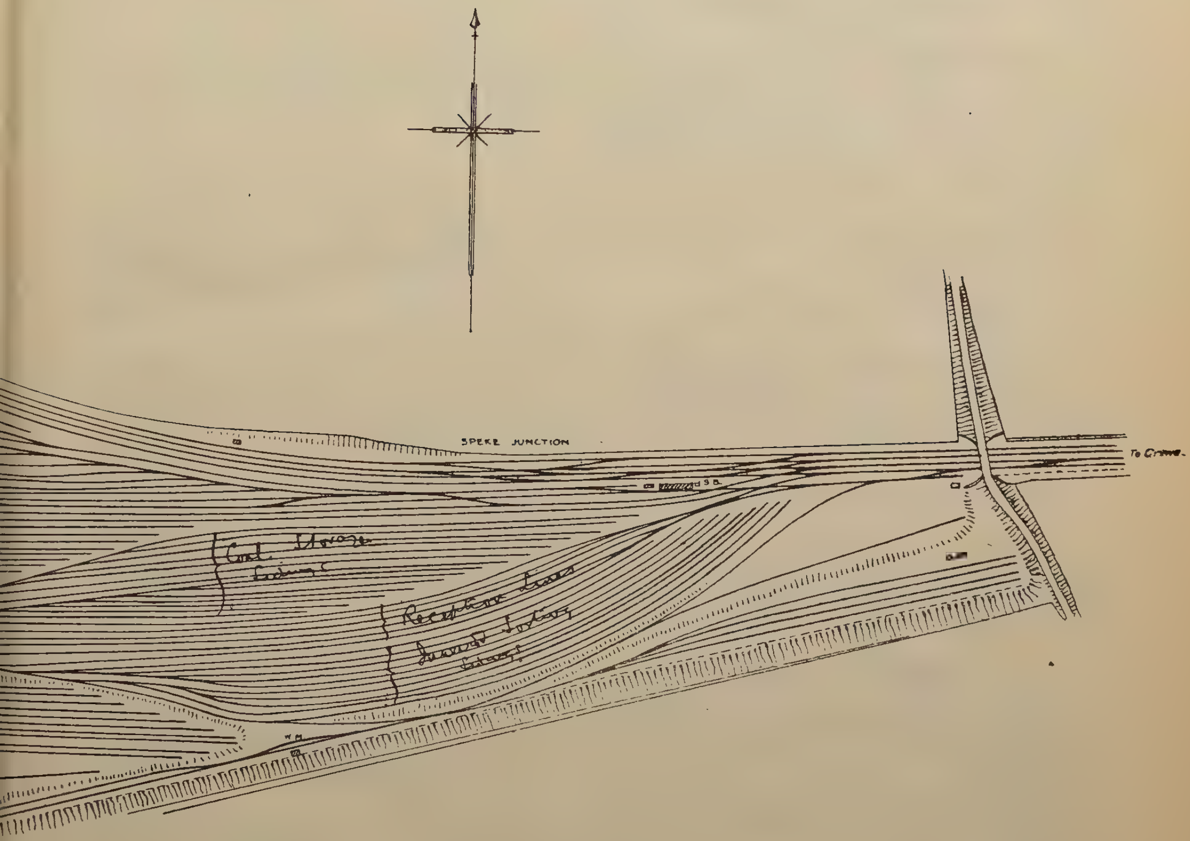
Locomotives are used, but many shunting movements are done by hand.

In the new lay-out capstans will be used.

Turntables are used at one small berth.

Switches are in general use.

Traversers would be convenient but are considered to be too expensive and slow in operation.



London Midland & Scottish Railway.

Madras and Southern Mahratta Railway.

By locomotives and hand shunting by coolies.

Turntables are used to some extent.

Ceylon Government Railway.

By locomotives.

Federated Malay States Railways.

By locomotives and hand shunting on certain wharves. Tow motors are being considered. Capstans are to be installed on certain jetties.

There are turntables and switches on all wharves.

New York Central Lines.

By steam locomotives.

The lines are connected by switches and this method is preferred as the quickest and most economical means.

Pennsylvania Railroad.

At Philadelphia :

By locomotives, except at the grain unloader where loaded cars are placed by locomotives and moved into and out of the structure by means of an electric winch.

Switches are used and are considered the best for the purpose.

Baltimore and Ohio Railroad.

Steam locomotives are used, except for placing cars on the car dumper at Curtis Bay yard, for which purpose a mechanical puller is employed.

Norfolk and Western Railway.

Loaded cars are shunted to the pier by locomotives and the contents unloaded to the quay. Cars are also loaded from the quay which is level with the car floors.

Reading Company.

Locomotives are preferred on account of flexibility and efficiency.

Switches.

Buenos Ayres Great Southern Railway.

By locomotives.

Capstans and traversers are used.

Buenos Ayres and Pacific Railway.

By locomotives.

Japanese Government Railways.

By locomotives.

Switches are used and these are found to be most convenient.

Railway Bureau, Government General of Chosen

By locomotives.

Switches.

Both are considered quick and economical.

South Manchuria Railway.

Small locomotives and tractors are used on the quay lines; carriages, electric tractors and carts on the cart roads.

Switches.

QUESTION 12.

a) *Please describe in succession the movements in connection with the placing and withdrawing of wagons from these lines, according to the method of working adopted.*

b) *What is the maximum number of wagons which can be placed at one time for loading or unloading per berth, or section of quay?*

c) *Can the placing and removal of wagons be done at any time during the day and night, according to the rate of loading or unloading, or only during certain hours?*

d) *In the latter case, what period of interruption to the loading or unloading is necessary?*

London and North Eastern Railway.

Leith :

b) At the coaling appliances from 40 to 80 loaded wagons, and from 20 to 50 empty wagons.

At the various quays and sheds from 10 to 40 wagons.

c) At any time.

d) No interruption.

Hull, King George Dock :

b) 50 per berth.

c) At any time.

d) Without interruption. The work is usually done between noon and 1-0 p. m. and after 5-0 p. m.

Immingham :

b) Up to 300 wagons can be placed on the quayside roads at the South West Arm, the berth being 1 250 feet long, and 200 on 1 and 2 commercial quays.

c) At any time.

d) No interruption. The work is usually done during a meal hour and after dock work ceases.

Parkeston Quay :

b) An average of 20 wagons per berth.

c) At any time.

d) There is no interruption. The bulk of the work is done at night.

London Midland and Scottish Railway.

a) Empty wagons going to the berths are brought down by means of locomotives to within reach of the quay capstans, which place the wagons alongside the ship. In the reverse direction loaded wagons are drawn out of the berths by capstan on to the weighing machines, passed over the machines, and placed in position for removal by locomotives.

b) 20 wagons.

c) At any time.

d) In certain berths the removal of loaded wagons and the replacement of empty wagons interferes for a few minutes with the discharging of the ship.

Great Western Railway (Great Britain).

b) The number of wagons placed alongside ship is usually sufficient for at least half a day's work. About 50 wagons can be placed alongside.

c) At any time.

Southern Railway (Great Britain).

Goods for shipment :

a) Wagons are shunted in shunting ground according to yards; hauled to yards; reshunted to sheds; hauled to shed; when offloaded pulled out of shed and replaced by full wagons.

Goods for railway :

Empty wagons are put into shed. When all wagons are loaded, or at noon and 5-0 p. m. full wagons hauled to shunting ground and trains made up.

If necessary, further supply of empties put in shed.

All the above work is performed by shunting locomotives.

b) 100 on front lines and on two lines at sheds 38 and 39.

c) At any time.

Canadian National Railways and Canadian Pacific Railway.

c) At any time. Scheduling of the work expedites movement.

d) Shed storage prevents delays to loading and unloading.

South African Railways and Harbours.

Durban :

a) Cars required for shipment are placed alongside the ship so that work may commence at 7-0 a. m. daily.

c) Cars are withdrawn and reset as and when required. Advantage is taken of meal hours and the quays shunted after the completion of the day's work. When a ship is working continuously for 24 hours the trucks are set and withdrawn as required and the shunting is continuous.

d) In the latter case the interruption is negligible, the loaded cars being set down on the top of empties, or vice versa.

South African Railways and Harbours.

Table Bay :

a) Cars on entering the harbour are sorted at a group of sidings and convey-

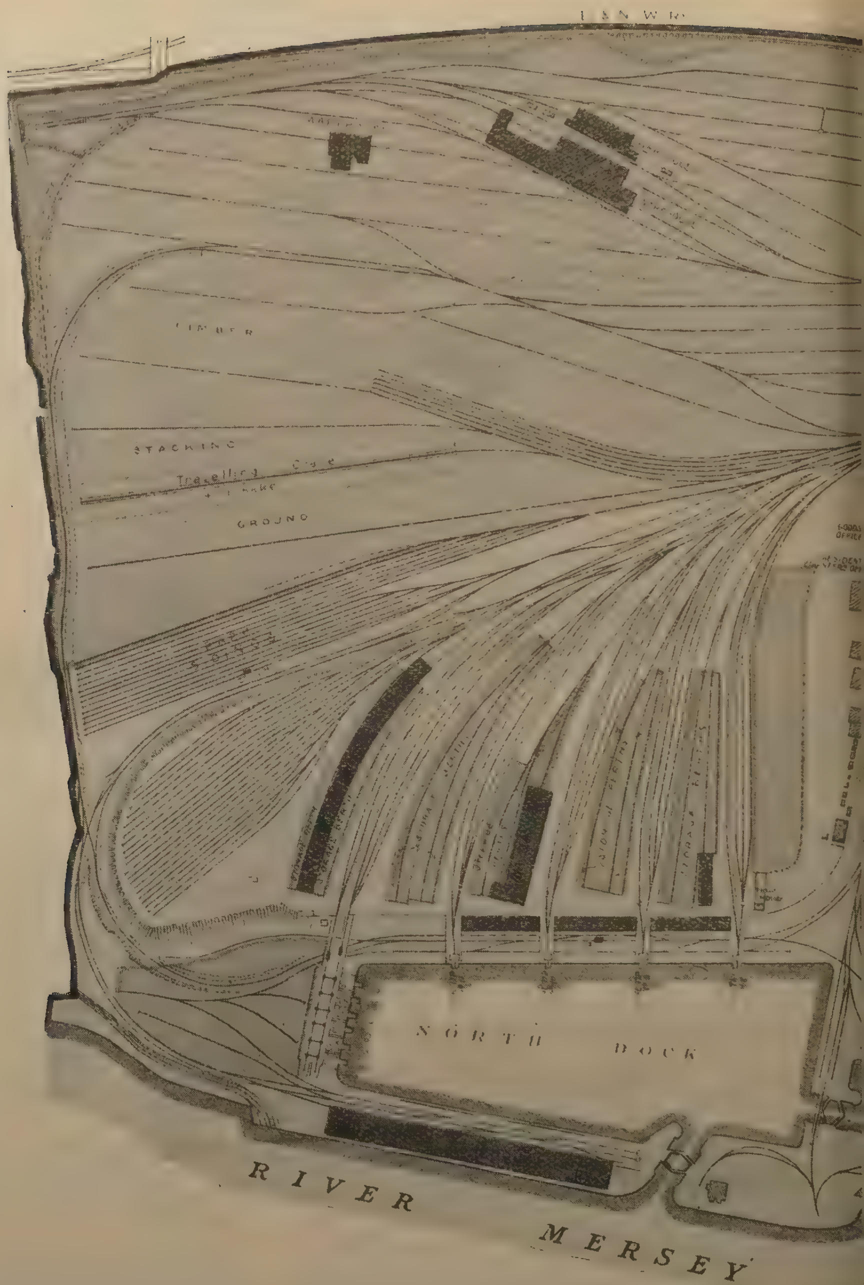
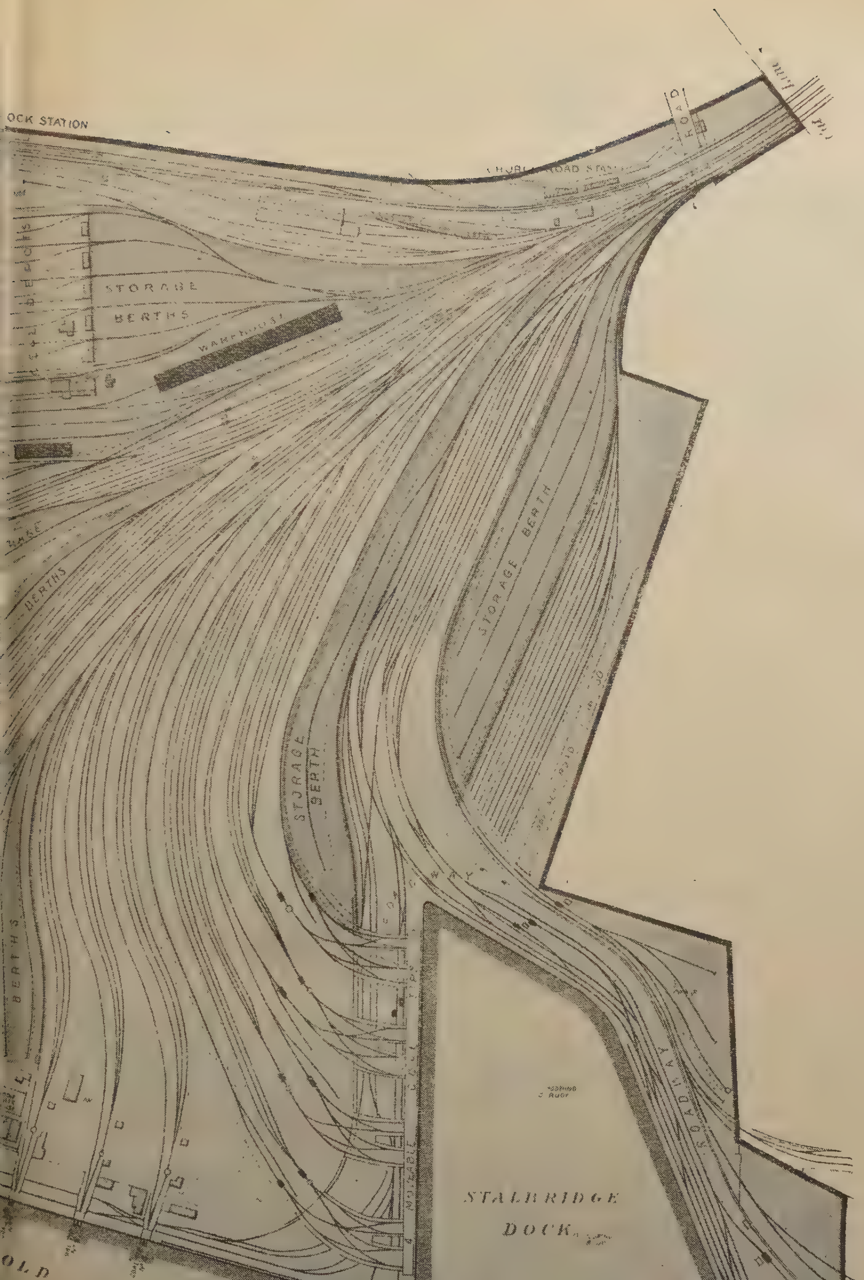


Fig. 9 — Garston Docks,

Scale :



and & Scottish Railway.

inch.

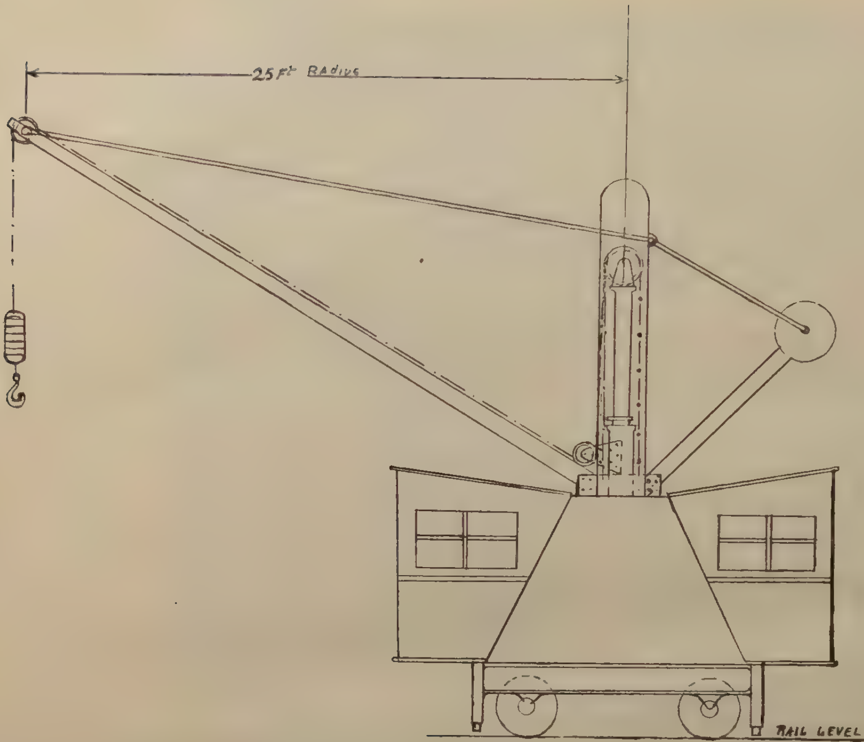


Fig. 10-A. — 30-cwt. hydraulie cranas, Garston Docks, London Midland & Scottish Railway.

Height of lift : 25 feet above and 23 feet below rail level. Total : 48 feet.
Liftung speed : 8 feet per second.
Turning speed ; 1 revolution in 4o seconds.

ed to the respective quays for unloading. When empty they are drawn out, made up into train loads, and despatched inland.

b) From 22 to 25 short vehicles.

c) At any time. Usually at meal times or after cessation of work.

d) One hour, if performed during working hours.

Gold Coast Government Railways.

c) At any time.

Sudan Government Railways & Steamers.

Imports :

a) Wagons placed ready in advance in the berth as soon as the latter known, and description and quantity of cargo ascertained. Removed thence during meal hours to warehouse for despatch, or to rehandling plant for sorting.

Exports :

Wagons brought from warehouses to berth and unloaded direct to ships sling, or dumped on ships berth prior to arrival of ship. Wagons from up country are brought direct to ship and unloaded.

Exports :

b) For convenient working 20 wagons per berth.

c) With the new lay-out it will be possible to move wagons at other than meal

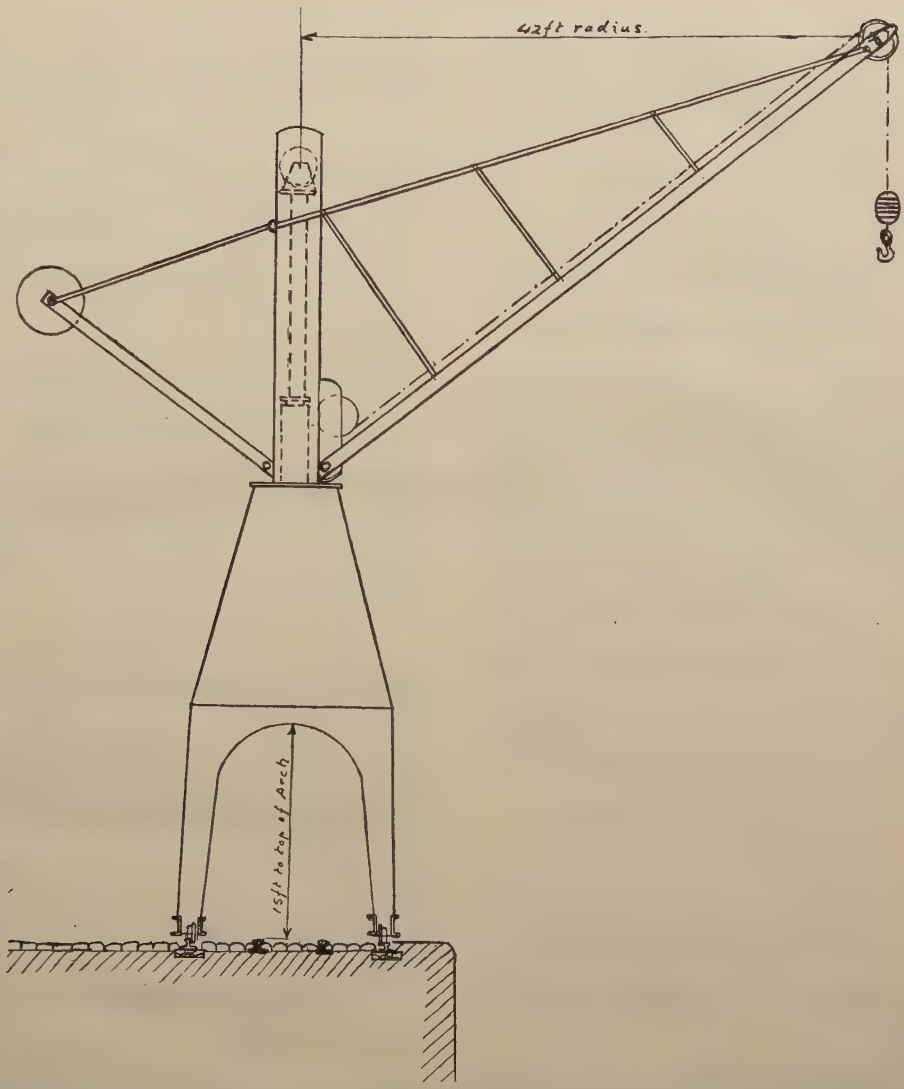


Fig. 10-B. — 50-cwt. and 4-ton cranes, Garston Docks, London Midland & Scottish Railway.

Height of lift : 50 feet above and 30 feet below rail level. Total : 80 feet.

Lifting speed { 50-cwt. crane : 7 feet per second.
4-ton crane : 5 feet per second.

Turning speed { 50-cwt. crane ; 1 rev. in 33 second.
4-ton crane ; 1 rev. per minute.

times. At present movement is rectricted to meal hours normally.

d) If movement effected outside meal hours with quays full the interruption is from one to two hours, according to the berth.

New South Wales Government Railways.

a) Cars are placed in position by locomotives and empties cleared by capstans and locomotives.

b) Approximately 15 to 20 cars under most favourable conditions.

c) At any time.

d) Approximately 15 to 20 minutes.

North Western Railway, India.

a) Wagons are collected on the grids where they are partly grouped for hatchways, but much of the grouping is done while moving the wagons from the grids to the wharf sidings. Empties are turned out into one line and removed to the grids by locomotives. Much of the work is done by hand.

c) Wagons can be placed at any time.

Madras and Southern Mahratta Railway.

a) Wagons are loaded alongside the storage sheds, taken to the sorting grid, and sorted to berth and hatchway.

b) About 30 to 35 wagons.

c) At any time.

d) About half an hour.

Ceylon Government Railways.

a) The wagons are placed in position and taken out when loaded without delay.

b) Siding accommodation is available at different points to receive from 10 to 50 wagons.

c) At any time. Railway work at Colombo port is carried out between 7-0 a. m. and 5-0 p. m.

Federated Malay States Railways.

a) At No. 6 wharf : Cars are placed by engine; the railway lines are parallel to the wharf edge. At Nos. 1 and 3 wharves shunting is by engine to and from shed lines, then by hand pushing on to wharves.

The provision of capstans is under consideration.

b) At No. 6 wharf : 30 four-wheeled vehicles per berth.

At Nos. 1 and 3 wharves: 8 four-wheeled vehicles.

c) At any time.

d) At No. 6 wharf : a stoppage of 20 minutes, the number of times per day depending on the rate of discharge.

Nos. 1 and 3 wharves : Two lines on jetty to each wharf allows a constant supply with use of turntables. No stoppage is necessary, except to get wagons over turntables.

New York Central Lines.

a) Shunting engines place and remove cars at the piers.

b) On pier No. 6, Weekhawken; used principally for unloading automobiles into lighters or ships : 80 cars, 40 feet long, can be placed.

On pier K, Weekhawken, 40 cars can be placed.

c) At any time during the day or night.

Pennsylvania Railroad.

At Philadelphia :

b) On the longest quay the maximum number of cars that can be placed on any one track is 35.

c) At any time during the day or night.

At Sandusky :

a) Tracks at the dock are filled with cars containing coal as ordered, and as fast as the cars are dumped into boats additional cars are placed until the cargo is completed.

b) 200 cars at each dumper.

c) At any time during the day or night.

At New York :

b) 250 loaded cars can be placed on the open dock at Greenville at the same time. The cars are loaded to and from lighters which are transferred to the steamships at the various piers.

c) At any time, usually at noon, 6-0 p. m. and midnight.

d) Interruption occurs if movement is done while unloading.

Baltimore and Ohio Railroad.

a) The agent in charge of the piers issues orders to the yard forces for cars which are required for unloading, stating where each car is to be placed. A record is kept by the yard forces shewing the time orders are received and complied with.

b) At piers Nos. 3, 5, 6, 8 and 9 used for handling merchandise and general cargoes there are 16 berths. The track capacity of these piers is 280 cars, an average of 18 per berth.

It is also the practice to have a large part of the vessel's cargo unloaded on the pier floor awaiting its arrival, and sufficient space is provided on the pier to hold a large part of the cargo the vessel brings in, so that while some of the incoming cargo may be moving direct to cars another part may be deposited on the pier for storage and later shipment. Outgoing cargo is similarly dealt with at the same time.

c) Cars can be placed at any time during the 24 hours, but the work is generally performed at stated periods in order to avoid, as far as possible, interference with the loading and unloading work, and is generally done during the change in shifts or at lunch periods.

Norfolk and Western Railway.

b) Pier capacity differs, e. g. 55, 20 and 66 cars.

c) Yes.

d) An interruption of from 15 to 30 minutes to the work on one side of the pier.

Reading Company.

a) By locomotives.

b) At the car unloader, cars are placed singly and unloaded one at a time.

On pier about 16 cars can be placed at the various berths.

c) Yes.

Buenos Ayres Great Southern Railway.

a) Wagons are placed in position and withdrawn by capstans, traversers being used to place the wagons on one track preparatory to being hauled from the port by shunting engines.

b) The maximum number of wagons is 15 45-ton vehicles placed on three tracks parallel to the vessel.

c) Wagons can be placed and removed during day and night.

d) There is no interruption in loading or unloading operations.

Buenos Ayres and Pacific Railway.

a) By locomotives only.

c) Yes, provided no interruption to discharging operation occurs, otherwise outside stipulated working hours.

Japanese Government Railways.

c) The work is done during certain hours only on account of the customs house officers business hours. The loading of wagons generally cannot be done before noon.

Railway Bureau, Government General of Chosen.

c) At any time.

South Manchuria Railway.

a) Wagons are placed in position and removed by small locomotives.

b) The maximum number of wagons is 50 for each single track on each pier.

c) Wagons can be placed and removed at any time during the day and night.

QUESTION 13.

What are the advantages and disadvantages of the lay-out of the lines described? What modifications do you suggest in order to remedy any defects ?

London and North Eastern Railway.

At Leith, King George Dock and Immingham the lay-out is satisfactory.

At Parkeston Quay a feeding line at the West end of the quay would be advantageous.

London Midland and Scottish Railway.

The principal disadvantages of the lay-out at Garston is that it necessitates the removal of loaded wagons before empty wagons can be put into position. It would be avantageous if loaded wagons could be removed from the berth at one end and empty wagons put in at the other.

Great Western Railway (Great Britain).

The lay-out of the lines at Cardiff has been arranged in the most advantageous manner to suit the quays.

Southern Railway (Great Britain).

The present lay-out at Southampton enables three drafts of wagons to be dealt with in each shed.

Disadvantages not apparent.

South African Railways and Harbours.

At Durban the growth of the port does not allow of any re-arrangement but extensions would be made as suggested in No. 5.

At Table Bay the present arrangement of three lines of rails on the quay allows 4 or 6 hatches of a vessel to be worked at the same time. The crossovers at various points on the quay avoid disturbing ships working at adjoining berths.

Sudan Government Railways.

Lay-out on quays is in course of alteration.

New South Wales Government Railways.

No modifications suggested.

North Western Railway, India.

On the East wharf the switches restrict the useful length of sidings in front of each berth.

Madras and Southern Mahratta Railway.

There is only one shunting neck, and there are long leads for loads from sheds to ship. These defects are being remedied.

Federated Malay States Railways.

On No. 6 wharf a third line in centre, with crossover roads from the outside lines would allow of shunting without so much interference with loading.

New York Central Lines.

No modifications are required.

Pennsylvania Railroad.

At Philadelphia :

The arrangement permits of direct switching movements to and from ship's side and is satisfactory.

At Sandusky :

The arrangements provide track capacity for the average cargo at each dock and for gravity movement from portion

of dock tracks to haulage mule at the foot of incline to car dumpers.

The disadvantages are the lack of track capacity for maximum cargoes and the necessity of having locomotives available at all times to push cars over the summit of the dock tracks for gravity movements to the dumpers.

At port of New York :

No modifications are contemplated.

Baltimore and Ohio Railroad.

The arrangement is satisfactory at Curtis Bay, also at Locust Point having regard to its location.

Norfolk and Western Railway.

The arrangements are satisfactory.

Reading Company.

See question 5.

Buenos Ayres Great Southern Railway.

The existing lay-out provides for a sufficient number of wagons being placed alongside at one time to allow of operations being continued during a shift of 4 hours without interruption.

Japanese Government Railways.

The arrangements at present are satisfactory.

Railway Bureau, Government General of Chosen.

It is considered desirable to so arrange the lines on or near the quays so that the greater part of a steamer's cargo may be placed alongside at one operation. Local conditions, however, make such an arrangement difficult.

South Manchuria Railway.

The arrangement is satisfactory.

QUESTION 14.

If the works mentioned above had still to be reconstructed what modifications, in form and size, would you recommend in order to obtain the most favourable lay-out of the lines from the point of view both of the railway service and the general working of the port?

London and North Eastern Railway.

Leith :

The present arrangement could not be improved, having regard to the available land.

Hull, King George Dock.:

No alterations would be made.

Immingham and Parkeston Quay :

Apart from a complete reconstruction no improvement could be made.

London Midland and Scottish Railway.

The ideal lay-out would be such as to enable all wagon movements to be in one direction, and two belt lines would be necessary, the inner being used for the supply of empty wagons to the quay berths, and the outer for the clearance of loaded wagons from the berths.

There should be independent connections from the « empty » line to each berth, and from each berth to the outer line. Such an arrangement entirely depends upon land being available.

The form and size of the quay berths is dependent upon the land available round the docks and between the docks and the river or sea frontage.

Great Western Railway (Great Britain).

The lay-out is generally satisfactory as a whole, although it might be possible to improve the lay-out in certain places if the works had to be reconstructed.

Southern Railway (Great Britain).

Having regard to the restricted area the present lay-out would be difficult to improve upon.

Canadian National Railways and Canadian Pacific Railway.

Present lay-out is considered adequate to handle present traffic.

South African Railways and Harbours.

At Durban the present lay-out is satisfactory with the additional wharfside lines suggested in No. 5.

At Table Bay, none, except in regard to greater facilities being afforded on the quayside for handling rail traffic, with a view to more economical working.

Sudan Government Railways & Steamers.

The old lay-out entails much interruption by shunting when necessary at other than meal times — there is a lack of sorting and storage area and rehandling plant : this is being remedied.

New South Wales Government Railways.

None.

North Western Railway, India.

The new West wharf at Karachi is under construction. There will be four lines in front of the quay. The two nearest the quay will be used for cars; the third line will be used as a shunting line, and the fourth line will serve the transit sheds.

There are three transit sheds, each of which has a separate grid leading to sorting sidings. Modern luffing cranes have been installed and capstans will be used in the absence of locomotives.

22 wagons can be placed on the line next the wharf, and 32 on each of the other two car lines.

Madras and Southern Mahratta Railway.

If costs were not prohibitive it would probably have been better to have arranged the quays in the form of jetties taking off obliquely from a common base.

New York Central Lines.

None.

Pennsylvania Railroad.

At Philadelphia :

Piers of the proper width to accommodate sufficient trackage to enable cars to be placed and removed with the least interruption to loading or discharging, and if the quays are covered, tracks should be laid between the edge of the quays and the sheds (apron tracks) to permit the direct loading or unloading of open top cars.

At Sandusky :

An additional track capacity should be provided to accommodate maximum cargoes and summit of grade on load tracks should be located far enough from dumpers to allow the whole of the cars to gravitate to the dumpers in order to avoid the use of locomotives.

At Port of New York :

The present facilities are satisfactory.

Buenos Ayres Great Southern Railway.

It would be difficult to improve the present lay-out.

Japanese Government Railways.

The arrangements are satisfactory.

Railway Bureau, Government General of Chosen.

Various improvements are under consideration, and a definite decision has not yet been come to.

South Manchuria Railway.

The arrangement is satisfactory.

QUESTION 15.

a) *In the case of jetties, which arrangement do you prefer : jetties at right angles to the bank or dock wall, or oblique to it?*

b) *From the railway point of view, what angle gives the best access to the jetties?*

c) *What width of jetty do you regard as the minimum?*

d) *What observations have you to make with regard to the length of the jetties?*

London and North Eastern Railway.

a) and *b*) The angle of the jetty depends on the space available and the direction of the approach lines, and whether the water space in front of the jetties permits easy approach by ships.

c) About 150 feet.

d) Not shorter than the longest ship to be accommodated.

Great Western Railway (Great Britain).

a) Jetties at right angles to the bank or dock wall have been found satisfactory.

b) Is largely dependent upon the site available. Direct access from the railway would be preferable and the angle of the jetty should, if possible, be arranged to meet this.

Gold Coast Government Railways.

a) A dock wall or quay is preferred to jetties.

c) 300 feet.

d) 800 feet.

New South Wales Government Railways.

a) Oblique.

b) An angle of 125° from the bank.

c) 150 feet for a single length jetty, i.e. 600 feet long.

d) For average conditions four-berth jetties, 1 200 feet long, 300 feet wide, with 300 feet of water between jetties, have been found most suitable.

North Western Railway, India.

a) This depends on the approaches to the jetty. Excessive curves, turntables, and traversers are to be avoided.

b) An angle of 45° would give a reasonable amount of curvature. Smaller angles would be better still from the railway point of view, but the space occupied by the jetties would become excessive.

c) This depends on whether transit sheds, etc. are required. Without sheds, space for four railway tracks and a dumping ground seems advisable.

d) This depends on the probable growth in the size of shipping.

Madras and Southern Mahratta Railway.

a) and *b*) Oblique.

Ceylon Government Railways.

a). Jetties at right angles to the quay are preferable for barge and lighter traffic.

c) Jetties should not be less than 28 feet in width for barge traffic.

d) Depends on the purpose for which they are required.

Federated Malay States Railways.

a) Oblique.

b) At an angle which allows of a safe curve in the railway line to the jetty.

c) A sufficient width for two lines on a single berth jetty with cross-overs to facilitate shunting. Traversers may save space.

d) This depends on the type of vessel regularly using them. Space must be allowed for bollards beyond the length of the vessel.

New York Central Lines

a) The jetties are approximately at right angles to the bank. The arrangement depends upon the location and water space available.

c) Depends upon the commodity handled. The piers vary from 64 feet to 200 feet.

d) This varies, being limited by the pier head line. They are from 300 to 1 200 feet in length.

Jetties should be long enough to accommodate one or more vessels, according to requirements.

Pennsylvania Railroad.

a) Piers at right angles are preferred, provided there is sufficient space available.

c) This depends entirely upon the character of the business handled, and whether the tracks are in the centre or at the sides of the pier, and also upon the kind of freight dealt with.

d) The piers are from a thousand to 2 000 feet in length. 1 000 feet is considered the minimum for covered piers.

Baltimore and Ohio Railroad.

a) Piers at right angles.

b) The angle of the piers with the bank is generally governed by the circumstances of the particular situation.

c) The circumstances of each case will determine the economic width, and depends on the use to be made of the ground space.

d) This depends on the physical limitations of the site. The length of the pier should be a multiple of the average length of the vessels usually berthed there.

Norfolk and Western Railway.

a) At right angles.

b) At right angles.

Buenos Ayres Great Southern Railway.

b) From the railway point of view the best access is obtained at right angles to the dock wall if there are railway approach lines from both sides of the jetty.

c) Jetties should be of sufficient width to allow of four railway trucks being laid down parallel to each berth.

d) Local requirements have a bearing upon the question of the length of jetties.

South Manchuria Railway.

b) Under the present arrangement the jetties are at right angles to the bank : plans are under consideration to place them oblique to it in future.

QUESTION 16.

a) *Do you experience difficulty in satisfying at the same time the interests of the railway and the port?*

b) *How can these be reconciled?*

London and North Eastern Railway.

a) Generally speaking, no.

London Midland and Scottish Railway.

a) As the Railway Company is the owner of the docks no difficulty is experienced.

Southern Railway (Great Britain).

a) Generally speaking, no.

Canadian National Railways and Canadian Pacific Railway.

b) Co-operation between the port authority and the railways reconciles any difficulties which may arise.

South African Railways and Harbours.

a) Being under the control of one administration the interests of the port and railway sections are not in conflict.

Sudan Government Railways & Steamers.

a) The first duty of the port is to clear ships and give them despatch. This requires an adequate wagon supply to clear the quays, and sufficient sorting and stacking area. With a limited wagon supply composed of main line wagons, the two interests are often diametrically opposed, and this could only be remedied by an adequate supply of dock wagons to meet all demands.

New South Wales Government Railways.

a) No.

North Western Railway, India.

a) Yes, there is a lack of co-operation between shippers, merchants, and railway. Shippers are afraid of incurring demurrage and restrict their orders in the first instance, supplementing them by last minute orders which prevent systematic and economical working. Merchants do the minimum amount of separation of commodities on the storage platform; wagons are loaded indiscriminately, and the Railway Company is relied upon to sort out and group the wagons for the various steamers. Delays occur, and there is a lack of co-operation in organising the loading.

Madras and Southern Mahratta Railway.

a) Difficulties have arisen in the use of wagons, but it is hoped to overcome these by allocating to the port its own wagons.

Ceylon Government Railway.

a) No.

New York Central Lines.

a) The interests of the port and the railroad are mutual and there is no difficulty in co-ordination.

Pennsylvania Railroad.

At Philadelphia :

a) There is necessarily divergence of opinion as to what is to the best interest of the railway and the port.

b) It is generally possible to reconcile these differences.

At Sandusky :

a) No difficulty.

At Port of New York :

a) No.

b) The relations with the port of New York authorities are entirely harmonious.

Baltimore and Ohio Railroad.

a) It is generally found that that which is to the best interest of the port, i. e. the public interest, would be to the benefit of the railway, and there is generally no conflict at individual ports.

The structure of freight rates sometimes finds the interests of different ports served in opposition.

b) In the latter case the different interests of the railway sometimes cannot be reconciled with the interests of the port and it is the practice in this case to follow a policy of neutrality.

Norfolk and Western Railway.

a) There is very little difficulty.

b) By frank discussion.

Reading Company.

a) No.

b) By close co-operation and friendly interchange of ideas by all interests involved.

Buenos Ayres Great Southern Railway.

a) Trouble is experienced at times, chiefly due to the difficulty of timing arrivals of merchandise to meet shipping requirements.

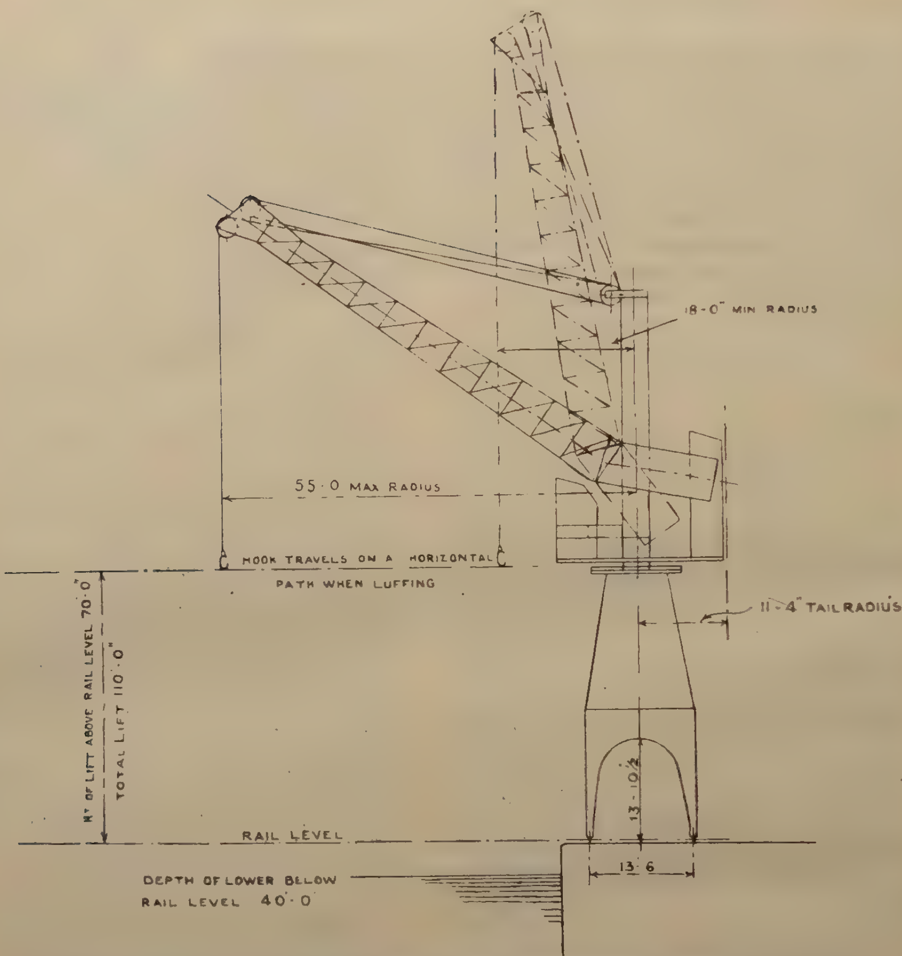


Fig. 12. — Diagram of Stothert & Pitt 1 1/2 and 3-ton hydraulic cranes, Cardiff Docks (East Bute Dock), Great Western Railway (Great Britain).

Vessels are often held up and the Railway Company cannot always deliver the traffic at the port with absolute precision.

b) By mutual recognition of the difficulties besetting each case.

Buenos Ayres and Pacific Railway.

a) No.

Japanese Government Railways.

a) No.

South Manchuria Railway.

a) The port belongs to the Railway Company, and both rail and port are under one authority called the « Wharf Office . Any difficulties which arise are easily adjusted.

SECTION II.

Loading and unloading appliances.

QUESTION 17.

a) *What types of cranes are employed? Which do you prefer?*

b) *Please indicate briefly the lifting capacity; lifting and turning speed, and the radius: also the type (travelling, fixed, etc.).*

c) *How do these appliances affect the circulation and placing in position of wagons?*

Kindly attach a very simple plan of the appliance.

London and North Eastern Railway.

Leith :

a) Moveable hydraulic cranes.

b) 1 1/2, 2, 3, 6 and 10-ton capacity.

a) Moveable electric cranes.

b) 2 and 3-ton capacity.

a) Locomotive steam cranes.

b) 3 to 5-ton capacity.

c) No interference.

Hull, King George Dock :

a) Electric cranes. Electric luffing cranes preferred.

b) 1 1/2 to 25-ton capacity.

a) Floating crane.

b) 80-ton capacity.

c) No interference.

See sketches of cranes (fig. 5. — A to L).

Immingham :

a) Hydraulic, steam travelling and electric cranes.

b) 25 moveable hydraulic cranes.

Number.	Capacity.	Radius, feet.	Lifting speed, feet per minute.	Turning speed, feet per minute.
8	3 tons.	55	300	828
2	5 tons.	55	180	690
12	2 tons.	50	300	756
2	10 tons.	50	120	314
1	50 tons (fixed).	50	20	200

Nine electric cranes, 30 cwts. Lifting speed 150 feet per minute.

Five steam travelling cranes, radius 30 feet, lifting capacity 30 cwts, lifting speed 160 feet per minute.

Parkeston Quay :

Number.	Capacity.	Radius, feet and inches.	Lifting speed, feet per minute.	Turning speed, feet per minute.
a) 20 moveable hydraulic cranes.				
b) 18 cranes.	1 1/2 tons.	28'6"	330	270
1 —	5 and 2 tons.	28'6"	100 to 200	110
1 —	12 and 5 tons.	28'6"	50 to 170	270
a) 8 hydraulic cranes in sheds.				
b) 6 cranes.	1 ton.	23'	230	470
2 —	1 —	12'6"	230	230

Number.	Capacity.	Radius, feet and inches.	Lifting speed, feet per minute.	Turning speed, feet per minute.
a) 10 electric moveable cranes.				
b) 3 portal.	30 cwts.	29′10 3/8″	220	400
2 semi-portal.	30 cwts.	29′10 3/8″	220	400
1 pedestal.	5 tons.	29′10 3/8″	100	400
1 portal.	5 tons.	29′10 3/8″	100	400
1 semi-portal.	5 tons.	29′10 3/8″	100	400
1 portal.	5 and 8 tons.	29′10 3/8″	50 to 100	400
1 portal.	30 tons.	36′ max. 28′ min.	12 1/2 to 30	75
a) 3 electric cranes in sheds				
b) 3 cranes.	20 cwts.	29′10 3/8″	75′	440

All these cranes have proved satisfactory.

London Midland and Scottish Railway.

a) The whole of the cranes, except a 40-ton electric sheer legs, are hydraulic.

b) Capacity from 30 cwts to 4 tons.

In most cases they are moveable and can be adjusted to plumb the hatches of different sized ships.

The jibs are non luffing.

Four 7-ton electric luffing cranes, with grabs, are in course of erection.

30-cwt crane, lifting speed 480 feet per minute, turning speed 1 revolution in 40 seconds, radius 25 feet.

50-cwt crane, lifting speed 420 feet per minute, turning speed 1 revolution in 33 seconds, radius 42 feet.

4-ton crane, lifting speed 300 feet per minute, turning speed 1 revolution per minute, radius 42 feet.

c) Wagon movements are not interfered with.

The cranes are moveable, and can be placed where required.

See sketches of two cranes (figs. 10 A and B).

Great Western Railway (Great Britain).

a) For goods other than coal — hydraulic, electric and steam cranes are used. Luffing jib type of crane is preferred.

b) The capacity varies from 35 cwts to 8 tons.

a) One special berth is provided with a heavy crane.

b) Capacity 70 tons.

a) There is a floating crane.

b) Lifting capacity 125 tons.

See sketch 1 1/2 and 3-ton hydraulic crane and photographs of 125-ton floating crane and hydraulic coal hoists (figs. 12 to 14).

Fig. 13. — 125-ton floating crane, Cardiff Docks, Great Western Railway (Great Britain).

Electric coal-shipping hoist, Cardiff Docks, Great Western Railway (Great Britain).

Southern Railway (Great Britain).

a) Electric, hydraulic and steam.

Electric level luffing gantry travelling cranes preferred.

b) 18 Toplis Monorope level luffing cranes :

Two of 5 tons, radius 90 feet,

Lifting speed,	100	feet	per	minute.
Slewing —	0.89	rev.	—	—
Luffing —	120	feet	—	—
Travelling —	50	feet	—	—

Three 5-ton, radius 65 feet.

Lifting speed,	100	feet	per	minute.
Slewing —	1.31	revs.	—	—
Luffing —	120	feet	—	—
Travelling —	50	feet	—	—

Nine 2-ton, radius 65 feet.

Lifting speed,	200	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	160	feet	—	—
Travelling —	50	feet	—	—

One 5-ton crane, radius 86 feet,

Lifting speed,	100	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	120	feet	—	—
Travelling —	50	feet	—	—

Three 2-ton cranes, radius 86 feet,

Lifting speed,	200	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	160	feet	—	—
Travelling —	50	feet	—	—

14 « Mitchel Williams » level luffing cranes :

Six 5-ton, radius 60 feet,

Hoisting speed,	100	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	120	feet	—	—

Four 2-ton, radius 60 feet,

Hoisting speed,	200	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	160	feet	—	—

Four 1 3/4-ton, radius 60 feet,

Hoisting speed,	200	feet	per	minute.
Slewing —	1.25	revs.	—	—
Luffing —	160	feet	—	—

The travelling gear of these cranes is operated by hand gearing.

South African Railways and Harbours.

a) At Durban, electric and hydraulic cranes. Electric cranes are preferred and hydraulic cranes are being replaced by electric appliances.

b) 3 and 4-ton travelling electric and hydraulic cranes; radius 52 ft. 6 in.; turning and travelling speed of 4-ton cranes : 400 feet per minute at maximum radius.

One 50-ton fixed electric crane.

b) At Table Bay the following cranes are employed :

One 15-ton crane.

Radius 55 feet.

Lifting speed :

15 tons at 25 feet per minute.
7 ½ tons at 50 feet — —

Auxiliary hook, 3 tons.
Radius, 57 ft. 6 in.

One 7-ton crane (fixed jib).

Radius 40 feet.

Lifting speed :

7 tons at 40 feet per minute.
3 ½ tons at 80 feet — —

Slewing speed,
7 tons at 300 feet — —

24 4-ton cranes.

Four cranes :

Maximum radius, 52 ft. 6 in.

Hoisting speed :

4 tons at 125 feet per minute.
2 tons at 250 feet — —

Luffing speed,
4 tons at 100 feet — —

Slewing speed,
4 tons at 400 feet — —

Travelling speed, 50 feet per minute (light).

Eleven cranes :

Maximum radius, 52 feet.

Lifting speed :

4 tons at 90 feet per minute.
2 tons at 180 feet — —

Slewing speed,
4 tons at 400 feet — —

Six cranes :

Maximum radius, 52 feet.

Lifting speed :

4 tons at 125 feet per minute.
2 tons at 250 feet — —

Luffing speed,
4 tons at 75 feet — —

Slewing speed,
4 tons at 400 feet — —

Travelling speed, 50 feet per minute (light).

Three cranes :

Lifting speed :

4 tons at 125 feet per minute.
2 tons at 250 feet — —

21 3-ton cranes.

Maximum radius, 45 feet.

Lifting speed :

3 tons at 125 feet per minute.
1 ½ tons at 250 feet — —

Slewing speed,
3 tons at 400 feet — —

Sudan Government Railways & Steamers.

a) Fixed jib and luffing cranes. Fixed jib cranes are preferred. This preference is solely on account of local conditions and the type of staff employed as crane drivers who will not use luffing appliances.

Coal transporters originally supplied for that purpose are now used for loading and unloading certain types of cargo, as they save carrying by hand.

c) The appliances do not interfere with the circulation of wagons.

New South Wales Government Railways.

a) Stationary steam jib cranes; stationary hydraulic jib cranes; travelling electric jib cranes.

The latter are preferred.

b) Electric jib cranes — capacity 15 tons; 55 feet radius; hoisting speed 100 feet per minute; slewing speed 300 feet per minute at hook; travelling speed 100 feet per minute.

c) These appliances do not affect the circulation and placing of wagons.

North Western Railway, India.

b) On East wharf, Karachi, 5-ton and 35-cwt hydraulic cranes with fixed jibs which can be removed as required between berths.

One 30-ton and two 14-ton cranes.

One 30-ton floating crane.

On the new West wharf the berths are each equipped with five 2-ton electric luffing cranes straddling the second track from the wharf.

c) The cranes on the West wharf in extreme position foul the turn-outs at the end of each berth restricting its useful length and the free circulation of wagons.

Madras and Southern Mahratta Railway.

a) Steam cranes are used. Electric cranes are asked for in future.

b) Nine 1-ton cranes, radius 38 feet.

Six 2 1/4-ton cranes, radius 22 to 32 feet.

One crane, with 3 and 5-ton lifts, maximum radius, 35 feet.

It is proposed to replace nine 1 /2-ton cranes by 3-ton electric cranes, maximum radius 50 feet and to convert the others to electric drive in order to increase the crane capacity.

Ceylon Government Railway.

a) Travelling steam cranes.

Travelling electric cranes.

Portable electric cranes, and
Fixed electric cranes.
Electric cranes are preferable.

b) Lifting capacity from 30 cwts to 35 tons.

Lifting speed about 60 feet per minute.
Turning speed about 100 feet per minute.

Federated Malay States Railways.

a) Steam cranes. Electric cranes preferred.

New York Central Lines.

a) Travelling cranes; locomotive cranes and marine derricks are used; the travelling cranes are electrically operated.

b) Pier 11 is equipped with a two arm travelling crane, 10 and 20 tons.

Pier 6, where automobiles are handled — 2 travelling cranes 10 and 20 tons.
The travelling cranes span all tracks on the pier.
The marine derricks have a capacity up to 40 tons. All types are satisfactory for the services required from them.

c) Where marine derricks are used cars can be placed anywhere on the pier. They also increase the volume of traffic which can be handled on a pier in a specified time.

Pennsylvania Railroad.

At Philadelphia :

a) No crane facilities are furnished at any of the general cargo shipping quays, but cargo masts are provided for loading or unloading cargo in conjunction with the ships' tackle.

At Port of New York :

a) and *b*) On the open dock there are 4 gantry cranes — 3 of 10 tons and 1 of 20 tons capacity.

There are 8 tracks on the pier.

Cranes 1 and 2 span tracks 1 and 2; crane 3 spans tracks 7 and 8, and crane 4 spans tracks 6, 7 and 8.

Tracks 3, 4 and 5 are used for holding and sorting purposes.

There are 3 locomotive cranes for loading and unloading traffic between cars and ground.

c) The cranes do not interfere with the placing of cars.

Baltimore and Ohio Railroad.

a) At Locust Point Terminal there are no cranes. Ships cargoes are handled with the ships' tackle when required.

Norfolk and Western Railway.

a) Cranes are not usually employed. Moveable gantry cranes are preferred.

b) A locomotive crane is occasionally used travelling on the track; lifting capacity 20 tons; turning speed 3 revs. per minute; lifting speed 190 feet per minute; travelling speed 440 feet per minute.

c) The locomotive crane can be used for shunting wagons and placing them in position.

Reading Company.

a) Cranes are not employed.

Buenos Ayres Great Southern Railway.

a) Electric cranes are used and are considered the most suitable appliance.

b) The lifting capacity is generally 1 1/2 tons. There are others of 3, 5 and 20 tons.

Lifting speed 200 feet per minute.
Turning speed 2 revs. per minute.
Radius 30, 32, 35 feet.

The cranes are fixed when working and generally moved from berth to berth by hand; the larger ones are fitted with travelling motors.

c) The appliances do not affect the circulation of wagons.

Railway Bureau, Government General of Chosen.

a) As labour is cheap few cranes are provided and ships derricks are generally used. For handling heavy freight hand travelling cranes are in use.

b) Hand travelling cranes, capacity 5 to 10 tons (radius 15 to 20 feet), and a 35-ton crane (radius 20 feet).

South Manchuria Railway.

b) Two 50-ton floating cranes.
Five 5-ton floating cranes.
One 1 ½-ton part-travelling crane.
Six 3-ton part-travelling cranes.
Two 5-ton travelling cranes.
One 27-ton travelling crane.
One 45-ton travelling crane.
Two 2-ton crane tractors.

QUESTION 18.

What is the average tonnage dealt with at a quay adequately provided with the above appliances (in tons per annum per metre of quay length)?

London and North Eastern Railway.

At Leith :

325 tons per annum per metre.

At Hull King George Dock :

Up to 1 000 tons per metre per annum on general cargo quays.

At Parkeston Quay :

420 tons per annum per metre.

Great Western Railway (Great Britain).

The tonnage varies considerably, according to the description of traffic dealt with.

Southern Railway (Great Britain).

Import cargo, 207 tons per metre.
Export cargo, 320 — — —

South African Railways and Harbours.

At Durban 373 tons per metre of quay length.

At Table Bay varies according to nature of cargo, but may be up to 5 tons per metre *per day*.

Sudan Government Railways.

The export tonnage varies greatly, being seasonal. The average rate per metre of quay front :

January to June, 1926 . .	871 tons.
January to June, 1927 . .	1 078 —
July to December, 1926 . .	753 —
July to December, 1927 . .	811 —

The above rate includes coal and is tonnage handled by all means at the disposal of the port. Coal traffic has now been removed.

New South Wales Government Railways.

The maximum output of the tavelling electric cranes is 300 tons per hour.

North Western Railway, India.

The total length of the 17 steamer wharves at Karachi is 2 600 metres; the tonnage handled during 1926-27, imports and exports, was 1 200 000 tons, equal to 461.5 tons per metre. As the average number of vacant berths per day was 9 out of 17, each occupied berth handled approximately 870 tons per metre.

Madras and Southern Mahratta Railway.

200 lifts per working day per crane is considered a reasonable figure.

New York Central Lines.

At Pier 6, Weehawken, New York, 100 carloads of crated automobiles can

be delivered per day to ships or lighters.

On covered piers where flour and other package freight is handled, the average tonnage is 500 000 tons per annum, averaging approximately 1 850 tons per metre of pier per annum.

Pennsylvania Railroad.

At Port of New York :

During September, 1928, 73 936 tons were delivered to and received from lighters at Greenville terminal. This figure does not represent the maximum capacity of the piers.

Baltimore and Ohio Railroad.

Port of Baltimore :

At Curtis Bay coal pier, the water frontage is about 100 metres. The pier has a practical working capacity of 10 000 000 tons per year and a theoretical capacity of several times this amount. Due to the vagaries of the export coal trade, the pier has never been utilised to its capacity for any long period. The best record for one month is about 620 000 tons, but the actual annual tonnage averages about 2 000 000 tons, or about 20 000 tons per metre of water front occupancy.

At Locust Point the water front is approximately 1 080 metres. The following tonnages handled in a recent year are typical :

Coal (bunkering and local use)	386 666	tons.
Merchandise — exported	368 734	—
Grain	359 061	—
Merchandise — imported	632 052	—
	1 746 513	—

This represente an average of about 1 610 tons per metre of waterfront.

Buenos Ayres Great Southern Railway.

Ingeniero White Port :

200 tons of heavy goods, e. g. coal, per crane per 8 hours.

Railway Bureau, Government General of Chosen.

Varies from 700 to 1 000 tons per metre per annum.

South Manchuria Railway.

Port of Dairen :

In the year 1927 the average tonnage dealt with at a quay was 1 770 short tons per annum per metre of quay length.

QUESTION 19.

a) *Are certain quays or certain sections of quays used exclusively for particular classes of merchandise, fuels, minerals, foodstuffs, grain, timber, etc.*

What special equipment is provided for these traffics? Please describe it, attaching a plan 1/5000th scale, if possible, and describe the method of working; setting out the different operations in succession, and the length of time occupied by each.

b) *What is the maximum output of these installations?*

c) *What volume of each kind of traffic (tonnage per annum per metre of quay) do you consider necessary to warrant the provision of special equipment in order to increase the capacity of the quays?*

London and North Eastern Railway.

At Leith :

a) Coaling quays are equipped with :

1 hydraulic coaling crane, 20 tons capacity.

1 electric coaling crane, 25 tons capacity.

3 hydraulic coaling hoists, 20 tons capacity.

2 hydraulic coaling hoists, 30 tons capacity.

b) Over 2 250 000 tons have been shipped per annum.


OUTER DOCK
16 ACRES
INNER DOCK
10 ACRES
COAL BARGE DOCK
CARGO & PASSENGER SHED
CRAIN ELEVATOR
DOLPHIN
CATTLE MARKET
SOUTHERN RAILWAY
CANUTE ROAD
ROYAL CRESCENT ROAD
QUEENS TERRACE
QUEENS PARK
ORCHARD PLACE
BRIDGE ROAD
JOHN STREET
RIVER STREET
DOCK STREET
LIBERTY STREET
HIGH STREET
FRENCH ST
BUGLE ST
RAILWAYS TO TOWN QUAY
FLOATING DOCK
TOWN QUAY
ENGINE YARD
CARGO SHED
DOCK
TRAFALGAR DOCK

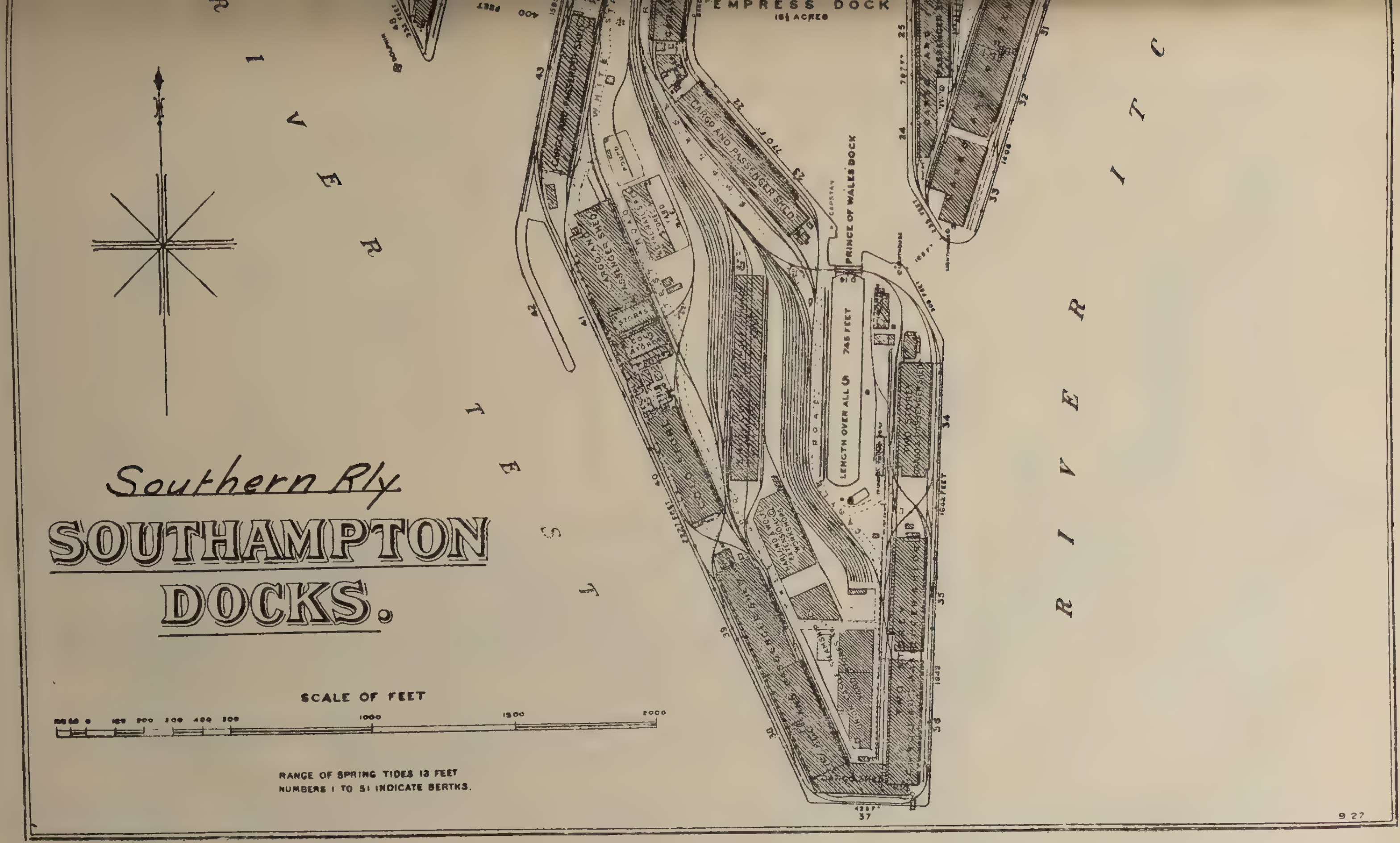

Southern Rly
SOUTHAMPTON
DOCKS.
SCALE OF FEET
RANGE OF SPRING TIDES 13 FEET
NUMBERS 1 TO 51 INDICATE BERTHS.
RIVER TEST
RIVER ITC
EMPRESS DOCK
16½ ACRES
PRINCE OF WALES DOCK
LENGTH OVER ALL 5 745 FEET
CARGO AND PASSENGER SHED
TWO STOREY CARGO & PASSENGER SHED
CARGO SHED
9 27

Fig. 15.

Fig. 16. — Table Bay Harbour (1928), South African Railways & Harbours.

Existing work shewn in full lines. — Future extensions shewn in dotted lines.

a) One grain berth with bucket elevator and two suction elevators discharging on to belt leading to grain warehouse.

b) Bucket elevator, 300 tons per hour. Suction elevator, each 30 tons per hour.

a) One grain berth with two suction elevators discharging on to a belt conveyor leading to grain warehouse.

b) Capacity 150 tons per hour.

At Hull, King George Dock :

a) 3 coaling berths; two equipped with long belts which lift coal from ground level to shipping height, and one with hydraulic hoists which lift wagons which are tipped at high level into delivery spout.

b) 600 tons per hour each.

a) No. 1 quay, 1 272 feet long; No. 3 quay, 1 350 feet long : equipped with 2 and 4 crane elevators respectively for discharging grain. There are also six portable elevators, the appliances discharging on to belts which convey the grain to a silo. The quays are also used for general cargo.

b) Capacity of grain elevators 120 tons per hour each.

Portable elevators 60 tons per hour each.

Immingham :

a) Coaling quays are equipped with 8 hydraulic hoists.

b) 700 tons per hour each.

a) On one quay a grain elevator.

b) 84 to 56 tons per hour per elevator.

c) Any regular traffic which cannot be dealt with at the rates required by ordinary crane equipment necessitates special appliances.

London Midland and Scottish Railway.

a) None of the quays are used exclusively for a particular business with the exception of one berth where bananas are handled. Banana traffic is discharged by means of elevators and conveyors. The elevators are placed in the ship's holds and extend over the dock to the quay, and working in conjunction with them are conveyors on the quays. Bunches of bananas are placed in the elevators in the hold, travelling upwards across the deck and down to the quay, at which point they are lifted by hand from the elevator on to the conveyors. From the conveyors the bunches are lifted by hand and carried to specially built banana vans : the distance from the conveyor to the railway vans being approximately 20 feet.

b) The approximate rate of discharge, with 4 elevators, is between 7 000 and 7 500 bunches per hour.

The maximum output is 8 000 bunches per hour.

Great Western Railway (Great Britain).

a) Certain sections on quays are allotted to private firms dealing with iron ore, patent fuel and grain. Hydraulic and electric cranes are used for all classes of goods. For iron ore, grabs are attached to cranes; for grain, a suction discharging elevator is used.

For coal shipping, hydraulic appliances capable of lifting a wagon of coal containing up to 20 tons are provided.

b) Suction grain elevator discharges 120 tons bulk grain per hour.

c) Before providing special equipment the dock owners would have to be satisfied that a reasonable amount of traffic was in prospect.

Southern Railway (Great Britain).

a) No, except timber. No special appliances are provided.

Spencers (Melksham) type of electric reversible conveyors are provided for wool. The apparatus is within the shed

and is used for connection between the ground and first floors of a double storey shed.

b) Working speed 5 miles per hour and band capable of conveying 9 bales — 1 ton, 7 cwt.

a) A Spencers fixed bucket elevator is provided for discharging grain.

b) Capacity 70 tons per hour.

Canadian National Railways and Canadian Pacific Railway.

a) Grain can be loaded to ocean boats at all the general docks, but there are special docks for receiving grain and also special docks for loading grain to ocean steamers. There are also special docks for receiving coal.

South African Railways and Harbours.

a) At Durban, yes; at Bluff quay, with the exception of an occasional shipment of whale oil in bulk, and landing of small quantities of explosives, this quay is used exclusively for the shipment of cargo and bunker coal.

The appliances consist of :

2 transporters.
2 dumpers.
1 belt conveyor plant, 740 feet in length.

Storage capacity of 10 000 tons in steel bins, and 60 000 tons open ground storage.

b) *Tonnage handled :*

Coal	1927	3 066 814 tons.
—	1928	2 703 172 —
Whale oil . .	1927	3 081 —
— — . .	1928	3 272 —

a) Island View is specially set aside for landing petrol, paraffin, and fuel oils in bulk, and for shipment of case and barrel oil, etc. ex factories adjacent. The petrol, etc. is pumped direct from tankers into storage tanks connected with the shore installation.

b) *Tonnage landed :*

1927	105 050 tons.
1928	174 136 —

a) Maydon Wharf is used extensively by importers of timber, etc., but is not equipped with cranes. Landing performed by ship's gear.

Elevator wharf : a grain elevator is established.

b) Storage capacity of 42 000 tons, shipping rate 1 000 tons per hour.

a) At Table Bay : terminal grain elevator.

b) Capacity : 30 000 tons grain can be shipped in bulk at 1 000 tons per hour.

Gold Coast Government Railways.

a) Separate berths are provided for coal, manganese and general cargo.

Sudan Government Railways.

a) Yes, New South quays have been reserved for fuel from 1928.

b) The special fuel transporters normal rate is 60 tons per hour per machine.

New South Wales Government Railways.

a) At a quay 1815 feet long, there are 6 travelling electric jib cranes solely employed on handling coal.

b) Tonnage handled in 1927 — 1 230 131 tons, equal to 2 220 tons per metre of quay length.

One 15-ton travelling electric jib crane to every 300 feet of quay is sufficient under existing conditions.

North Western Railway, India.

a) The only special berth at Karachi is the oil pier where tankers discharge their cargo by pumping direct into storage tanks.

Ceylon Government Railways.

a) At Railway owned quays some are exclusively used for fuel. At Colombo

Port Commission, certain quays are reserved exclusively for :

(a) Exports.

(b) Imports and transhipment.

Exports. — In practice certain quays are generally used for export of certain goods, e. g. cocoanut oil, plumbago, tea, etc.

Imports. — Special quays are provided as under :

1. Quay adjoining the wharf station for heavy Government cargo.

2. Chalmers quay and warehouse for other Government goods.

3. Canal yard for private imports of iron work, heavy timber, cement, tar and other bulky cargo.

4. A special jetty for landing explosives.

5. Case kerosine is landed direct into trucks at Kochchikade.

6. At the graving dock there are special facilities for bulk kerosine, fuel oil, etc.

7. Certain warehouses are specially set aside for transhipment cargo, and the use of one of these is allowed, in emergencies, for imports and also receives imports by native sailing vessels.

8. Manure, except certain patent manures, are exclusively landed at Kochchikade. Cattle also are almost exclusively landed here.

b) At the railway owned piers there is no equipment for coal and pumps are used for oil fuel which could deal with 250 tons per hour.

Federated Malay States Railways.

No, with the exception that latex and socony oil is dealt with at the South end of No. 6 wharf where pipe lines are fixed.

New York Central Lines.

a) Yes. At Weehawken, New York, covered pier « K » handles automobiles already assembled on wheels.

Pier 6 handles automobiles in crates.

Pier 7 is used for grain exclusively and a grain elevator is provided.

Pier 11 is used for sulphur.

Pier 12 is used for ties and lumber.

At Pier 3 electrically operated lift trucks with skids are used for miscellaneous box-car freight, which is unloaded from car to skids which are taken by lift trucks out of the car to lighter or quay.

b) The travelling cranes on pier 6 can unload a car load of automobiles into ship or lighter in 8 minutes, handling from one to four cases per lift.

It takes approximately 30 minutes to unload a box-car carrying 35 to 45 tons of freight.

At pier No. 3 a car load of automobiles already assembled on their own wheels is unloaded in 45 minutes.

c) Any class of freight which at least takes up to 50 % of the capacity of the facilities of any pier.

Pennsylvania Railroad.

At Philadelphia :

a) At Greenwich coal pier there is a McMyler car dumper.

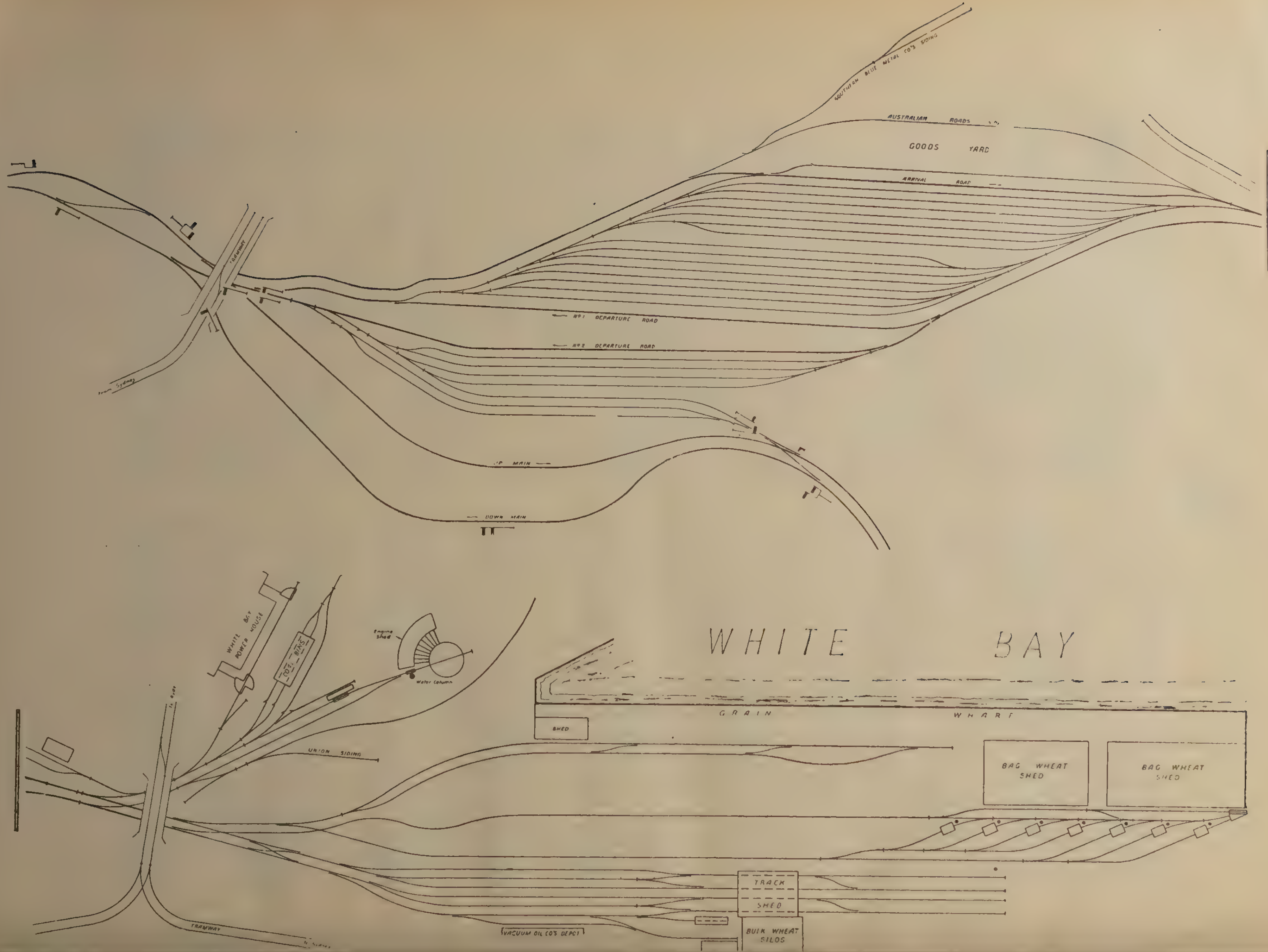
b) Maximum capacity of 30 cars per hour.

a) At the ore pier there are two McMyler ore unloading machines.

b) Maximum capacity of 127 tons per hour each.

a) At the grain pier there is a modern concrete grain elevator.

b) A capacity of 2 225 000 bushels; maximum discharging capacity to vessels 48 000 bushels per hour.



SOUTHERN BLUE METAL CO'S SIDING
AUSTRALIAN ROADS
GOODS YARD
ARRIVAL ROAD
No 1 DEPARTURE ROAD
No 2 DEPARTURE ROAD
UP MAIN
DOWN MAIN
TRAMWAY
WHITE BAY POWER HOUSE
Engine Shed
Water Column
UNION SIDING
WHITE BAY
GRAIN WHARF
SHED
BAG WHEAT SHED
BAG WHEAT SHED
TRACK SHED
BULK WHEAT SILOS
VACUUM OIL CO'S DEPOT
TRAMWAY

c) This should be indicated by the inability of the existing installation to cope with the quantity of traffic presented. Their character should be determined by the nature of the shipment offered .

At Sandusky :

a) The docks are used exclusively for unloading cars of coal into ship.

Unloading is accomplished by two car dumpers, one on each dock, each having a lifting capacity of 200 tons. Cars are dropped by gravity to the foot of the incline to dumper, from which point they are pushed up incline on to dumper by haulage mule, then elevated and turned over, dumping coal into pan terminating in chute to boat. Empty car is pushed off dumper by loaded car entering and runs over gravity swith back, incline back of the dumper and into empty car tracks.

b) Average time of complete dumping operation 1 1/2 minutes per car.

Record number of cars handled by one machine is 52 cars per hour for three-hour period.

Maximum tonnage handled is :

5 900 tons per hour.
73 987 tons per 24-hour period.
1 345 086 tons per month.

c) No general answer can be given. The equipment should, in all cases, be adequate to give the best possible dispatch to boats and be suitable for commodities handled.

At Port of New York :

a) Different types of piers are used for various commodities. Closed piers are used for handling cars containing commodities which may be damaged by exposure to the weather.

There is a grain unloader, and at South Amboy a coal dumping plant consisting of two coal dumpers.

b) The coal dumpers have a capacity of about 20 cars per hour under continuous operation. Cars range up to 140 000 lb. capacity each.

c) Volume of traffic has not to be considered so much as the character of the shipments. The necessity for providing special equipment is ruled by the inability of the equipment provided to cope with the traffic offering. The character of the equipment must be determined by the nature of the traffic offering.

Baltimore and Ohio Railway.

a) Yes, at Curtis Bay the pier is used exclusively for handling coal.

At Locust point a coal pier is also provided for unloading coal used for bunkering and local use.

Pier No. 7 is used exclusively for handling grain and grain handling equipment is also provided on Pier No. 6, which pier is also used for handling merchandise.

b) Curtis bay pier has a maximum practical capacity of 10 000 000 tons of coal per year. The maximum shipping capacity of the grain elevator is about 120 000 000 bushels of grain per year.

c) The extent to which any special equipment should be provided is mainly an economic question and should take into account the total benefits which are to be derived by the railroad, including the revenues derived from the use of the special equipment, the revenue from the freight haul, and other items, such as the effect that the movement and handling of these special traffics may have upon other traffics.

Norfolk and Western Railway.

a) Yes, for fuel.

b) Coal piers have a capacity of 1 500 000 tons per month, or 18 000 000 tons per annum. The tonnage handled depends entirely upon the type of vessel and amount of cargo offered; with open

top vessels which require little trimming the capacity can be doubled without increasing facilities.

Reading Company.

a) Yes, a car unloader and pier is provided for dealing with anthracite and bituminous coal and coke. The car unloader is operated on a pier 900 feet long, the unloader being in the middle with a capacity of 30 to 40 cars per hour; maximum lifting capacity 240 000 lb. Open top cars are used exclusively.

The cars are lifted one at a time in a cradle, which is turned over and the coal discharged into a pan, the outer end of which converges to a square telescope, in sections, which leads to the hold of the vessel.

A wooden trestle is also provided 900 feet long up which cars are pushed by shunting engines and from the summit they drop by gravity to several loading berths, the cars being discharged by opening the hoppers by hand, the coal flowing through chutes to the holds of the vessels.

The vessels are practically all open canal boats destined for domestic points, of a capacity from 300 to 1 500 gross tons, averaging 600 to 700 gross tons per boat.

A car dumper is also provided, the cars for which are placed in position by shunting engines which remove them, when empty, to the outward yard.

b) Average tonnage over the pier about one and a half million gross tons per annum.

Average coal tonnage over the car dumper about 3 million gross tons per annum.

Maximum output of car dumper: 6 million tons per annum.

Maximum output of car pier : 3 million tons per annum.

Buenos Ayres Great Southern Railway.

a) Yes, a mole carrying two elevators serves 4 berths for handling grain.

A mole serving 2 berths contains ten underground, electrically driven, belt conveyors, and carries grain discharged from wagons from the receiving hoppers to the holds of the vessels.

b) Five thousand tons per working day of eight hours can be received from wagons into the two elevators and discharged to vessels; a similar tonnage on the belt conveyor mole.

c) This depends on individual circumstances.

Japanese Government Railways.

a) At Wakamatsu there is a fixed hoist and a fixed crane, and there are chutes for shipping coal. The chutes are the most efficient appliances. Sailing ships load at this port.

b) Chute quay length : 677 metres. Average annual tonnage : 4 107 959 tons. Per metre of quay length : 6 068 tons.

Hoist quay length : 100 metres. Average annual tonnage : 654 021 tons. Per metre of quay length : 6 540 tons.

Crane quay length : 100 metres. Average annual tonnage : 693 381 tons. Per metre of quay length : 6 934 tons.

a) At Tobata there are three travelling coal hoists :

Lifting capacity, 18 tons.
Lifting speed, 30 metres.
Turning speed, 36 metres.
Travelling speed, 70 metres per minute.

From the drop bottom cars the coal falls into buckets under the jetty. The loaded buckets move outwards automatically and are carried to the hatchways by means of hoists. The buckets are discharged by releasing the bottom doors.

b) Quay length : 242 metres. Average annual tonnage 1 992 225 tons. Per metre of quay 8 232 tons.

a) At Otaru and Muroran, coal cars are pushed on to elevated jetties; one side of the car is opened and the coal loaded by means of chutes. The present wooden jetties are now being reconstructed. On completion loaded cars will move by gravity to a mule pit; then drawn up by the mule on to the elevated jetty, and the coal discharged on to a belt conveyor, carrying it to the loader by means of a tripper, the coal finally reaching the ship through a chute.

There will also be a storage plant from which coal will be loaded into cars by means of a grab carried on a bridge crane and belt conveyor, thence to the ship, or coal will be carried direct to the ship by the bridge crane.

b) The present capacity at Otaru where the quay is 394 metres in length is on an average 699 837 tons per year, or 1 774 tons per metre of quay.

At Muroran the quay is 579 metres long. Average annual tonnage: 1 463 473 tons. Per metre of quay: 2 527 tons.

The new elevated jetty will have a length of 277 metres to accommodate two vessels with a loading capacity of 600 tons per hour. The storage plant will be able to load at the rate of 200 tons per hour.

Railway Bureau, Government General of Chosen.

General merchandise, foodstuffs, and grain are handled at the same quay. Separate quays are used for fuels, minerals, and timber. The quantities are not large at present and are dealt with by launches.

South Manchuria Railway.

a) Yes, pier No. 1 has a special coaling equipment comprising lines for 250 loaded wagons; lines for 80 empty wagons; a mule; a car-dumper; belt conveyor and coaling machine.

b) The car-dumper is worked by electricity and can handle thirty 60-ton wagons per hour.

The belt conveyor capacity is 900 tons per hour. Provision is made for a second conveyor.

The coaling machine travels East and West along the quay to reach the ships' hatches, and has a capacity of 900 tons per hour. Provision is made for an additional machine.

a) The Pier at Jijiko is equipped for loading petroleum and bean oil. There are 12 oil tanks of 1 500 kgr. each.

b) Two 8-inch oil pipes. With these pipes two ships can be loaded at a time at the rate of 200 kgr. per hour.

PART III.

SECTION I.

Method of working the port.

SECTION II.

Tariff arrangements.

Section I.

Method of working the port.

QUESTION 20.

a) *Does the Railway Company serving the port bear the initial outlay of the railway installations?*

b) *If this is so, does the Railway Company recoup itself by means of a special charge on goods exported or imported?*

or are these expenses included in the general accounts of the Railway?

or are these expenses borne by the Port Authority?

c) *Are supplementary services dealt with in a similar manner?*

d) *Is the concentration yard considered to be part of the installation?*

London and North Eastern Railway.

Leith :

a) The railway lines and capstans on the dock estate are installed and maintained by the Leith Harbour and Dock Commissioners who are the Port Autorrity.

d) No.

At Hull, King George Dock, Immingham and Parkeston Quay :

a) Yes, the docks belong to the Railway Company.

b) Generally the railway conveyance rate is « Free alongside ship ».

c) In some cases additional charge is made.

d) Yes, at Immingham and Parkeston Quay.

No, at King George Dock, Hull.

London Midland and Scottish Railway.

a) Yes.

b) No, the railway accommodation at the port is covered by the terminals in the railway rates. The expenses are included in the general railway accounts.

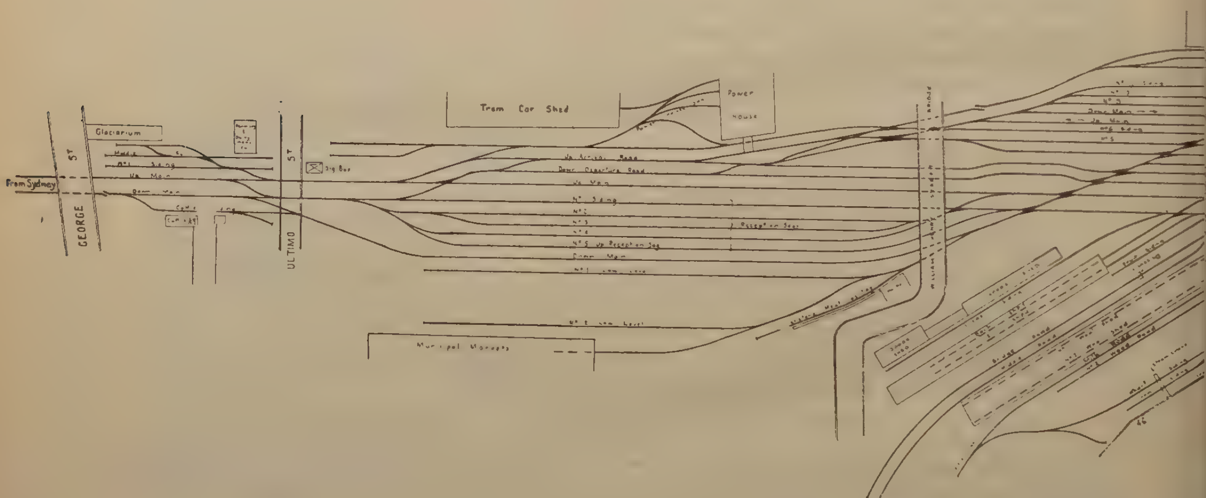


Fig. 18. — Diagram of Darling Harbour and

c) No, Speke junction sidings is outside the dock estate, and also serves the town of Garston and private sidings.

Great Western Railway (Great Britain).

a) The Great Western Railway Company owns the port and the railway installations.

b) Separate dock charges are collected for the dock services, and the Railway Company's annual accounts include special accounts for docks.

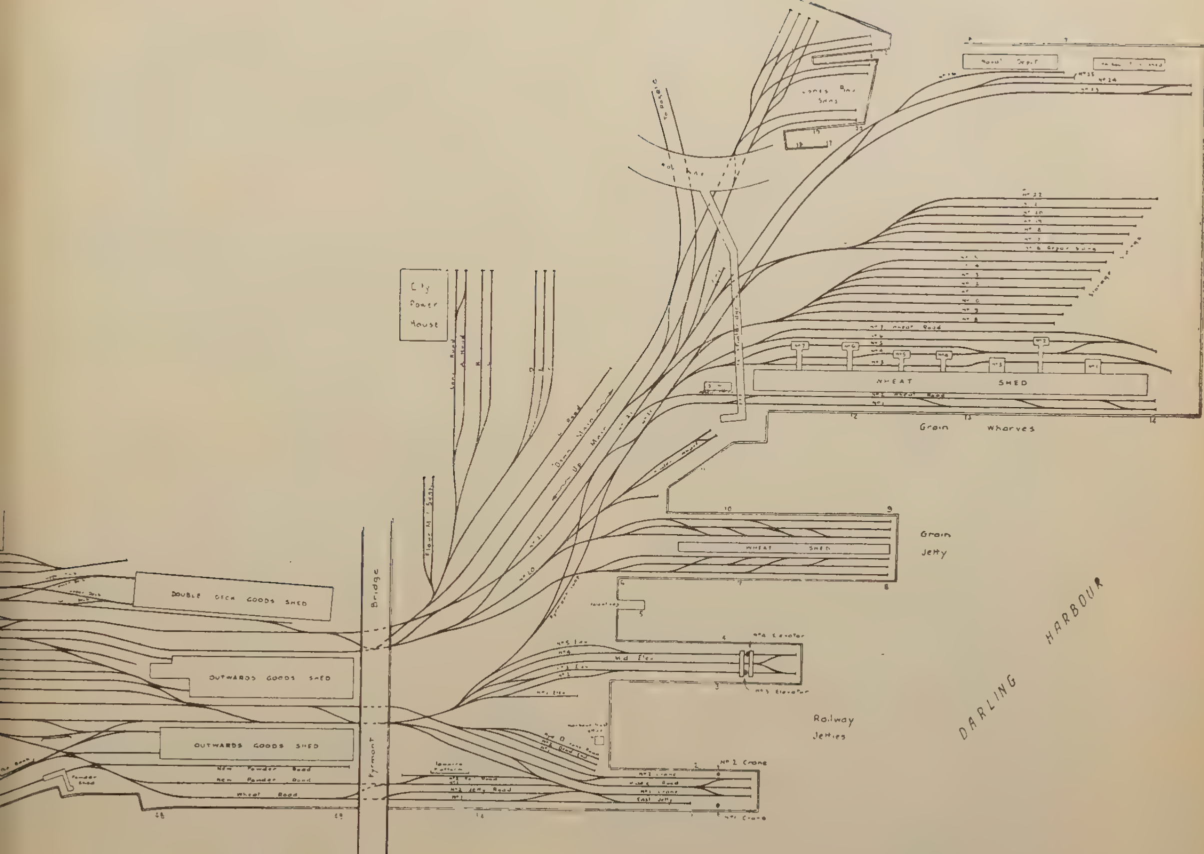
c) Yes.

d) Yes.

Southern Railway (Great Britain).

a) Yes, the docks are railway owned.

b) No, there is no separate railway



ard, New South Wales Government Railways.

toll; the expenses are included in the general railway capital accounts.

c) Yes.

d) Yes.

Canadian National Railways and Canadian Pacific Railway.

a) Only so far as the railway owned facilities are concerned. The balance is borne by the port authority.

South African Railways and Harbours.

a) All harbours and railways are owned and controlled by the South African Railways and Harbours of the Union of South Africa.

Sudan Government Railways & Steamers.

a) Yes.

b) No.

c) Yes.

d) No.

New South Wales Government Railways.

a) The cost of railway facilities installed to serve jetties is equally divided between the railway and the Harbour Trust Authorities.

b) No.

c) Supplementary services are charged for by shunting charges, hire of truck or ordinary mileage tariff.

d) Yes.

North Western Railway, India.

a) The railway owns several yards at Karachi and the Karachi Port Trust owns all the yards on its own property and bears the initial outlay.

The main concentration yards, inward and outward, are railway yards.

Madras and Southern Mahratta Railway.

a) The Railway Company works the port on behalf of the W.I.P., a Company guaranteed by the Portugese Government.

New York Central Lines.

a) Yes.

b) Yes, by a special charge.

c) Yes.

d) No.

Pennsylvania Railroad.

At Philadelphia :

a) On piers owned by the Railway Company the railway bears the initial outlay of the railway installations, but where owned by an individual or the City, such cost is borne by the owner of the quay.

b) There are no special charges on goods exported and imported, the Railroad Company absorbing any expenses.

At Sandusky :

a) The Railroad Company bears the initial outlay of the railway installations and costs are included in the general costs of the Railroad Company.

b) Special charge is made for dumping coal from cars into boats.

d) Yes.

At New York Harbour :

a) Yes, the installation being on railroad property.

b) The Railway Company makes no special charges for expenses incurred in the installations at the terminals, the only return being from the regularly authorised legal tariffs.

c) Supplementary services are dealt with in a similar manner.

d) Each Railroad has its own concentration or receiving yard which is considered a part of the installation.

Norfolk and Western Railway.

a) Yes.

b) There are wharfage and handling charges in addition to line haul charges. If to and/or from a rate territory where our competitors at other ports make a similar addition, or, with a deduction from the line haul rate when to and/or from a territory where our competitors include the wharfage and handling in the line haul rate. No expense in the handling of freight is borne by the Port Authority.

c) Supplementary services are provided for in tariffs, and are in addition to the line haul wharfage and handling charges.

Reading Company.

a) Yes.

b) The expenses are included in the general accounts of the railway.

c) Yes.

d) Yes.

Buenos Ayres Great Southern Railway.

a) The port is the property of the Railway Company and the latter bears the initial outlay.

b) The dock and permanence dues are collected by the Railway Company, also a tariff for haulage of wagons over the port lines.

These expenses are included in the general accounts of the Railway, which is the Port Authority.

c) Yes.

d) No.

Japanese Government Railways.

a) If a railway yard is constructed at a port on the initiative of the railway the latter bears the cost of the railway installations.

b) No special charge is levied on exported or imported goods.

a) If a railway yard is constructed by a port and a railway in co-operation the expenses are borne by both.

b) No special charge is imposed.

Railway Bureau, Government General of Chosen.

a) Initial and supplementary railway installations at the port are constructed at Government cost, and the railway does not bear this expense.

South Manchuria Railway.

The Railway Company controls Dairen Wharf and provides the whole equipment.

QUESTION 21.

a) *What organisation is responsible for the working of the port?*

If several organisations are concerned what are their respective duties, and especially which are the Railway Company responsible for?

Are the railway installations worked by a special organisation or by the Railway Company?

b) *How are relations established between the Port Authority and the organisation responsible for working, and between them and the shippers and ship owners (Chamber of Commerce, etc.)?*

London and North Eastern Railway.

At Leith :

a) The Harbour and Dock Commissioners are responsible for the working of the port. The Commissioners do no work in handling cargoes, with the exception of grain at their elevator warehouse. At all other berths stevedoring work is performed by the shipping companies or by stevedores working for them; this includes coal trimming and tipping. The Railway Company is responsible for railway haulage only in the docks.

b) By agreement between the parties.

At Hull, King George Dock, Immingham and Parkeston Quay :

a) The Railway Company owns and is responsible for working the port.

b) By dock superintendent or portmaster. At Parkeston the Railway Company is owner of most of the steamships using the port.

London Midland and Scottish Railway.

a) The Railway dock superintendent and staff.

The Railway Company are responsible

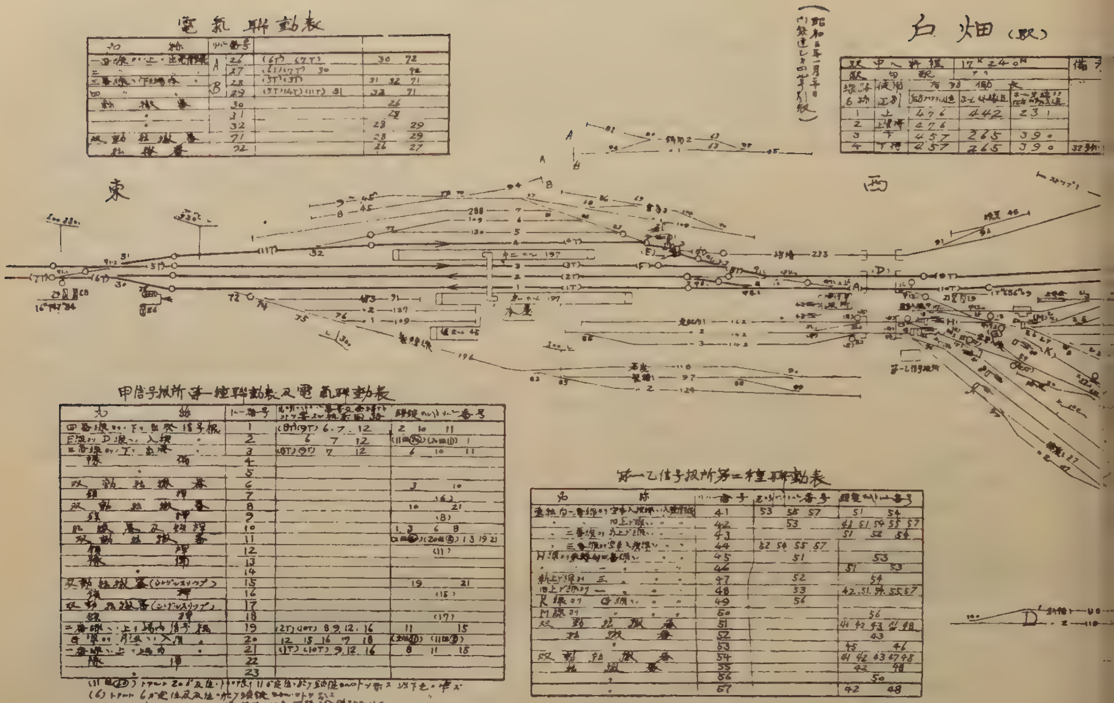


Fig. 19. — Tobata Sta

Explanatio

A = The lines for the arrival of trains.
C = The lines for receiving and shunting the
D = The lines for unloading the coal cars. Th
D' = The lines for unloading the coal cars. Th
E = The lines for returning the empty cars.
F = The lines for receiving the empty cars.
B = The lines for the departure of trains.
These items are enumerated according to

for the whole of the operations of both dock and railway.

b) Through the Railway Dock Superintendent.

Great Western Railway (Great Britain).

a) The Cardiff docks belong to the Great Western Company.

The railway installations are worked by the Railway Company.

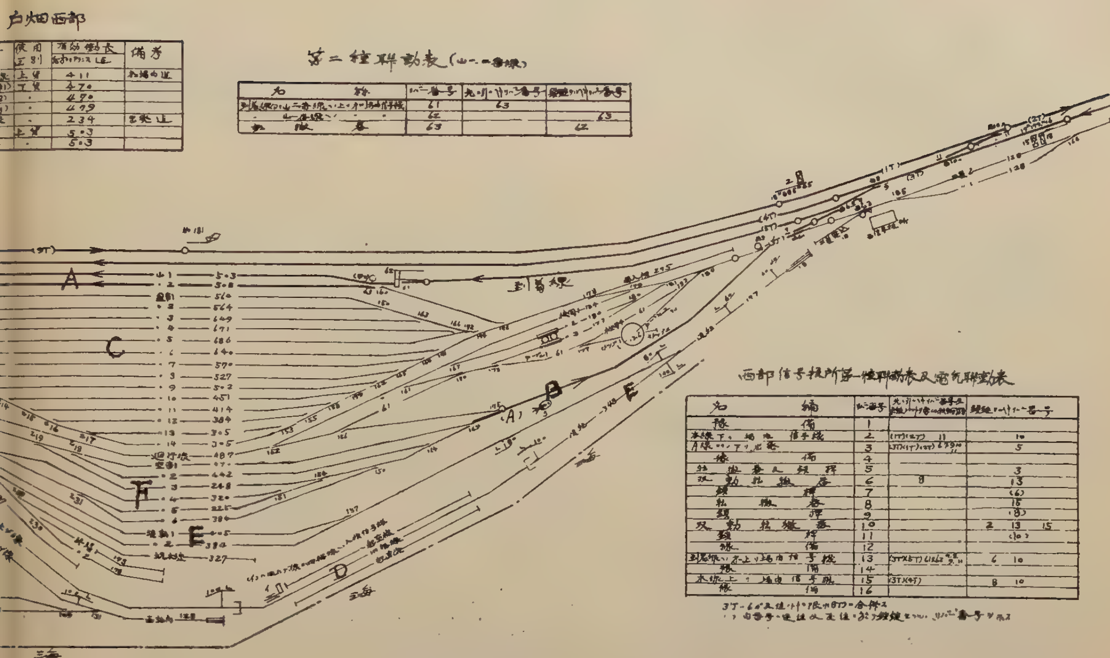
b) General relations are established through the traders organisations.

Southern Railway (Great Britain).

a) At Southampton there is dual control.

Southampton docks and an area of 600 feet around them are controlled by the owners — the Southern Railway Company.

Outside this area and Southampton Water is controlled by the Southampton



se Government Railways.

1, 6, 12, 17.

sferred on board by hoists.

osited in the storage plants provided at the jetty.

orking.

Harbour Board (a Statutory Body) who impose separate dues.

The railway installations are worked by the Railway Company's dock servants.

b) The work on shore is performed entirely by the Railway Company and the ships employ their own stevedores.

Canadian National Railways and Canadian Pacific Railway.

a) The Port Authority — « The Harbour Commissioners of Montreal » operates the harbour facilities, such as railway yards, grain elevators, and cranes.

South African Railways and Harbours.

a) The harbours being controlled by the State, the officers of the Administration are responsible. The port manager controls all shore work while the port captain is responsible for the marine work.

Sudan Government Railways & Steamers.

a) Sudan Government Railways and Steamers.

New South Wales Government Railways.

a) Sydney Harbour Trust Authorities.

The Railway Department controls two coal jetties and the loading at bagged wheat berths. The railway installations are worked by railway employees.

b) By periodical conferences between Railway and Harbour Trust Authorities with shippers and other organisations.

North Western Railway, India.

a) At Karachi, the Karachi Port Trust.

The railway installations are worked by the North Western Railway, with the exception of the work done in the Mansfield import yard where Karachi Port Trust shunting engines and staff are employed.

The railway deals direct with merchants, exporters, etc. for movements within the port area to and from the storage platforms leased by them from the Port Trust. Shippers place their orders for wagons with the Trust, who issue instructions to the railway for movements to the ship's berth. At the berth the stevedore gives instructions to the railway personnel regarding the sorting to hatchways.

b) The Board of Commissioners of the port is comprised of five members appointed by Government, including the divisional superintendent of the railway and the collector of customs. The Karachi Chambers of Commerce, European and Indian, are represented by six elected members, the Municipality by one elected member and the Buyers and Shippers Chambers by two elected members.

Ceylon Government Railway.

a) The Colombo Port Commission. The railway installations are worked by the Commission.

Federated Malay States Railways.

a) The Federated Malay States Railways, except that, as « Conservator » of the port, the harbour master has certain powers regarding explosives and issues instructions regarding mooring buoys.

New York Central Lines.

City of New York Harbour :

a) The Railroad Company assumes responsibility for movement of traffic between rail head and ship side or steamship dock.

Pennsylvania Railroad.

At Philadelphia :

a) The Board of Commissioners of Navigation regulates shipping in the harbour. The Railway is not responsible for any duties as to harbour shipping. The railway installations are worked by the Railway Company.

b) The relations between the railways and the shippers and the owners are direct.

At Sandusky :

a) The Railroad Company is responsible for handling loaded cars to point where they are handled by gravity and by haulage mule to dumper, and for handling empty cars beyond the point where they are run by gravity away from dumpers. Dock Company, the lessee of the Railroad Company, is responsible for handling cars between above described points, including operation of dumpers.

b) There is no local port authority at Sandusky. Relations are established by

direct contact with shippers of coal and with boat owners, also by indirect contact with boat owners through Dock Company which operates the dumpers and Lake Carrier Association.

At New York :

a) The New York Port Authority exercises supervision but does not operate any of the railway facilities at the port. Various railroads own their individual properties and are responsible for the working of their own facilities.

A portion of the railway operations are handled by contract labour under railroad supervision. The New York Port Authority does not control the operations of the various terminals, but there is a close liaison between the port authorities and the Railway Companies.

b) The ship owners have their own organisation for receiving and forwarding freight. They are in close contact with the railway traffic organisations in New York City, and make all arrangements for the movement of traffic interchanged between the railroad and the steamship lines. The Railway Company is represented in the Chamber of Commerce but this body does not control the operations of the railroad.

Norfolk and Western Railway.

a) The individial carriers entering the port are responsible for their individual operations. The carrier is responsible for the delivery of cars conveying exports to the berth of the steamer and their discharge into the berth, and for checking, weighing, loading and forwarding of imports from the loading point to destination.

The railway installations are worked by the Railway Company.

b) Relations between the Railway Company and the shippers and ship operators are established by railway employees set apart for that purpose.

Reading Company.

a) All operations are under the direction of the railway employees.

b) By close co-operation of all interests involved.

Buenos Ayres Great Southern Railway.

a) The Traffic Department of the railway is responsible for the working and the Railway Company is responsible for the whole organisation.

b) All arrangements are made direct between the Railway Company and the shippers, except the allocation of berths which is in the hands of a Government official.

Buenos Ayres and Pacific Railway.

a) The Ministry of Public Works.

Japanese Government Railways.

a) The Department of Communications is responsible for the entrance and exit of shipping.

The Department of Finance is responsible for the customs duty.

The Department of Home Affairs is responsible for the repairing and dredging of the port.

The Department of Railways is responsible for the construction of railways, and

The Railway Company, or the Government Railways are responsible for railway transportation.

Railway Bureau, Government General of Chosen.

a) The Customs House, the Railway Bureau, and the Ship Owners are responsible for the port working.

The Customs House governs customs, the Railway Bureau and Ship Owners deal with the traffic. The Railway Bureau undertakes loading and unloading

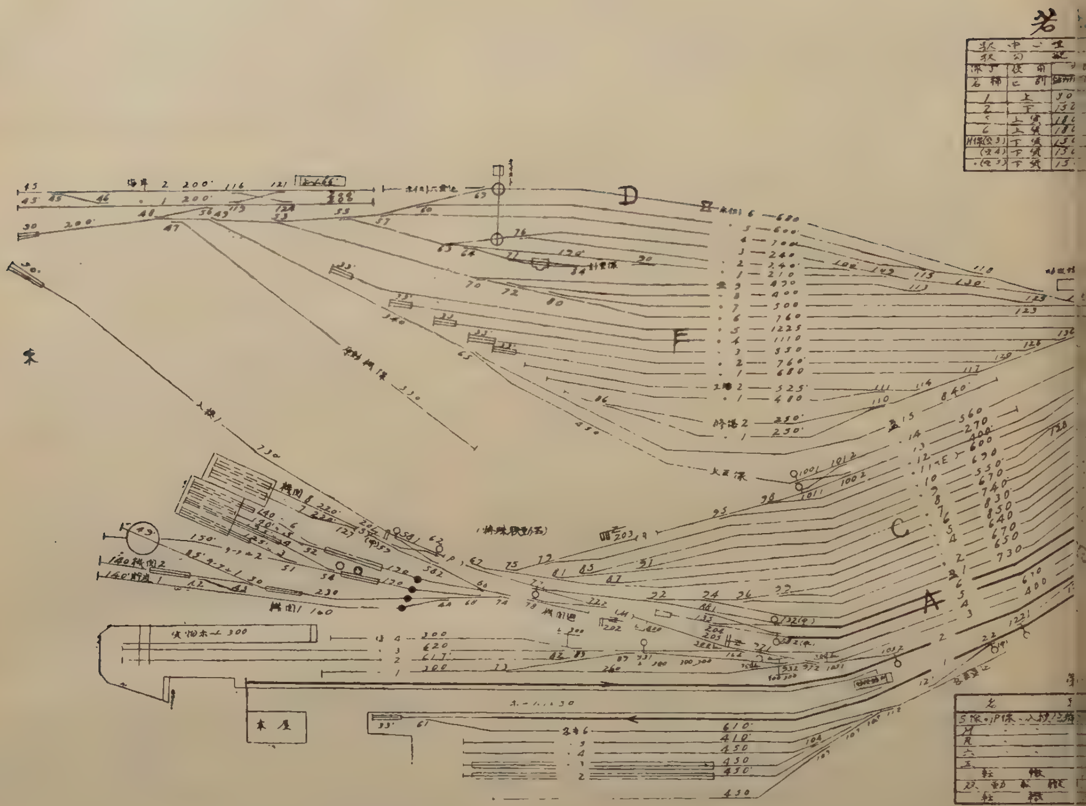


Fig. 20 — Wakamatsu S

Explanation

A = The lines for the arrival of trains.
C = The lines for receiving and shunting
C' = The lines for temporarily receiving t
D = The lines for unloading the cars for
D' = The lines for unloading the cars for
E = The lines for receiving the empty ca
B = The lines for the departure of trains.
These items are enumerated accordin

cars, storage of freight, and the execution of customs formalities for shippers.

The railway installations at the port (cranes, warehouses, etc.) are managed by the Customs House and the Railway Bureau, and the Ship Owners work under the surveillance of the Customs House.

South Manchuria Railway.

a) The Railway Wharf Office.

双動転轍器	21		5 7 9
〃	22		4 6 8 10
転轍器	23		33
〃	24		1 36
双動転轍器	25		1 10 32 34 36
〃	26		30 31
転轍器	27		30
〃 〃	28		
K線ヨリA線ヘノ入換信號機	29	22	16 17 18 19
新橋本線ヨリ中継五番線ヘノ 〃	30		26 27
〃 〃 六 〃 〃	31	27	26 38
五番線ヘノ上リ場内 〃	32	23 24	23 25
六 〃 〃 〃 〃	33	24	23 29
一 〃 〃 〃 〃	34		12 24 25
上リ遠方 〃	35	32又ハ33又ハ34	
転轍器	36		37

第二種聯動表

名稱	テコ番號	定位ニテ鎖錠スルテコ番號	鎖錠サレルテコ番號
二番線ヨリ下リ出発信號機	1		10 13 25 24
G線ヨリH線ヘノ入換 〃	2	14	
A 〃 H 〃 〃	3		15
D 〃 中継七番線ヘノ 〃	4	17	18 22
D 〃 F 線ヘノ 〃 〃	5	17 18	20 21
B 〃 中継七番線ヘノ 〃	6	16	18 22
B 〃 F 線ヘノ 〃	7		16 19 20 21
C 〃 中継七番線ヘノ 〃	8	19	22
C 〃 F 線ヘノ 〃	9		19 20 21
H線ヨリ下リ出発 〃	10	18 20	1 15 22 25
X線ヨリ新橋本線ヘノ入換 〃	11	26	
双動転轍器	12		36
転轍器	13		1
双動転轍器	14		
〃	15		3 10
〃	16		7 29
転轍器	17		29
双動転轍器	18		4 6 29
〃	19		7 9 29
転轍器	20		5 7 9

動表

…番號	鎖錠サレルテコ番號
…)	202 203 204 205
	201 203 204 205
	201 202 204 205
…2	201 202 203 205
…8	201 202 203 204

nese Government Railways.

1, 6, 12, 17.

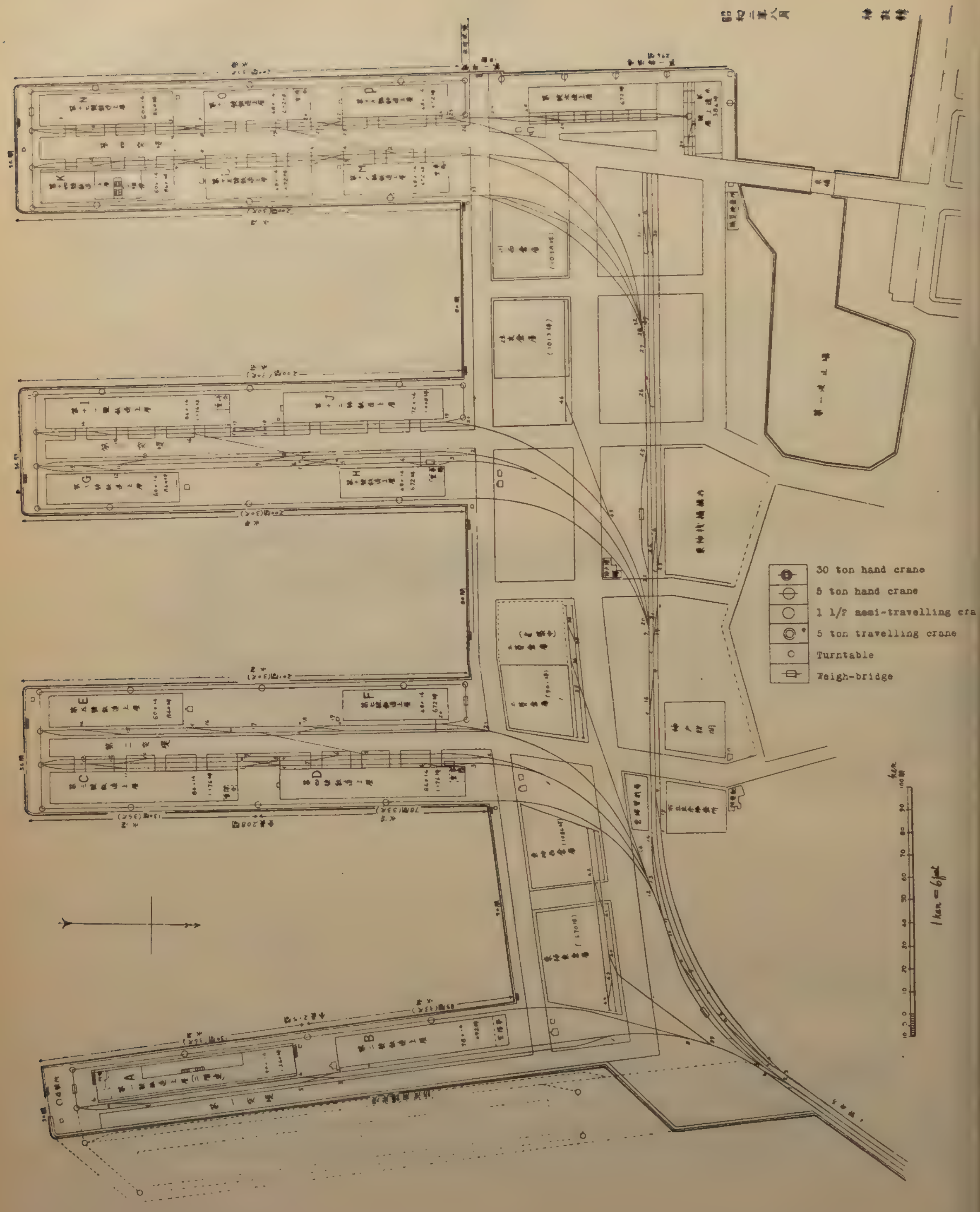
cars.
rs to the jetty.
ship.
he coal in the storage plants.

ual working.

b) All labour employed on the wharf area and on board ships is either supplied or approved by the wharf office, which is responsible for dealing with the general shippers and ship owners.

QUESTION 22.

a) *Are the lines serving the quays regarded as industrial sidings, or are they*



30 ton hand crane
5 ton hand crane
1 1/2 semi-travelling cra
5 ton travelling crane
Turntable
Weigh-bridge
1 ken = 6 feet

regarded as an extension of the ordinary traffic lines?

b) *Is the service of these lines gratuitous? If not, on what principle are the charges based?*

London and North Eastern Railway.

At Leith :

a) As extension of the ordinary traffic lines.

b) The Port Authority charges the railway companies 3/4 d. per ton on all goods and minerals hauled over the lines and, in addition, 2 d. per ton handled by capstans.

At Hull, King George Dock, Immingham and Parkeston Quay :

a) The docks are owned by the Railway Company and the question of apportionment does not arise.

London Midland and Scottish Railway.

a) As part of the dock equipment.

b) The charges are regarded as being in the rail rates.

Great Western Railway (Great Britain).

a) As extension of the ordinary traffic lines.

b) Charges are based on the class of traffic and the weight.

Southern Railway (Great Britain).

a) As extension of traffic lines.

b) No, the services are subject to tariffs.

Canadian National Railways and Canadian Pacific Railway.

a) The facilities comprise a separate railway organisation with yards, industrial tracks, team tracks and service tracks.

b) Service is paid for at specified rates for each type of service. These charges, so far as they relate to the movement of cars, are absorbed in the freight rate.

South African Railways and Harbours.

a) Yes, ordinary traffic lines.

b) Yes.

Gold Coast Government Railways.

a) As ordinary traffic lines.

b) Terminal charges incorporated in rates.

Sudan Government Railways & Steamers.

a) As ordinary traffic lines.

b) Service free.

New South Wales Government Railways.

a) As extension of the ordinary traffic lines.

b) Freight calculated on mileage basis from sending to destination stations where wharves are located.

North Western Railway, India.

b) The Karachi Port Trust impose wharfage charges and pay to the railway a haulage charge of 6 rupees, and a hand shunting charge of 10 rupees for every wagon booked from any yard, station, private siding, etc. within the port area to any vessel in the port. The loading is done by the consignors and the unloading by the Port Trust. The Port Trust also pay the railway for movements of wagons from the wharf to the import and other yards, sidings, etc. and between the import yard and other yards. The railway levies charges direct on the consignors for other yard to yard movements other than to and from the vessel or import yard.

Madras and Southern Mahratta Railway.

a) As extension of the railway traffic lines.

Ceylon Government Railways.

a) At Talaimannar as ordinary traffic lines.

Federated Malay States Railways.

a) As extensions of traffic lines.

b) A haulage charge is made for certain traffics, e. g. traffic to godown or open storage.

New York Central Lines.

City of New York Harbour :

a) As an extension of the ordinary traffic lines.

b) Service incident to the delivery of freight to ship is covered in the through freight rate.

Pennsylvania Railroad.

At Philadelphia :

a) The sidings on the piers are regarded as industrial sidings.

b) No special charges are made for the service on these lines, the cost being absorbed in the tariff rates.

At Sandusky :

a) Track serving docks are classed as yard sidings.

b) Regular road haul tariff rates include the use of these tracks, the only extra charge is for dumping cars into boats.

At Port of New Nork :

a) The lines are considered as part of the ordinary traffic lines, and are owned exclusively by the railroad.

b) No charge is made for the use of the terminal other than the charges authorised in the regular freight tariffs which have been approved by the Interstate Commerce Commission.

Norfolk and Western Railway.

a) As an extension of the ordinary traffic lines.

b) The services of these shunting lines are gratuitous if the Railway Company enjoys a line haul revenue, and additional charges are made if the traffic is brought to the Port via other railway lines and the shunting is performed on behalf of the latter railway. Some lines absorb these charges and some do not in which event the shipper or receiver pays.

Reading Company.

a) As an extension of the traffic lines.

b) Charges are raised based on the cost of operation with fair profit allowance.

Buenos Ayres Great Southern Railway.

a) The lines serving the quays are regarded as extensions of the ordinary traffic lines.

b) The haulage over the port lines is charged for at the rate of about 1 sh. 8 d. per ton on the total weight of goods transported in wagons.

Buenos Ayres and Pacific Railway.

a) Extension of ordinary traffic lines.

Japanese Government Railways.

a) When the Railway Company are responsible for the installation of the lines at the port they are regarded as an extension of the traffic lines.

b) In the above case the service is gratuitous, except when rates are charged on a mileage basis.

Railway Bureau, Government General of Chosen.

a) As ordinary traffic lines.

b) The working of these lines is gratuitous or not, according to the cost of

operation. Additional charges, based on the ordinary rate, are levied on wagons in the latter case.

South Manchuria Railway.

a) The lines are regarded as an extension of the ordinary traffic lines.

b) The services on these lines are chargeable.

QUESTION 23.

What are the regulations in regard to the time allowed for loading and unloading of wagons, and for the application of demurrage charges?

London and North Eastern Railway.

Except when the senders are instructed to forward a definite tonnage for shipment the ordinary demurrage regulations apply after the expiry of the free time.

London Midland and Scottish Railway.

The General Railway Clearing House demurrage regulations.

Great Western Railway (Great Britain).

The usual railway regulations apply.

Southern Railway (Great Britain).

The General Railway Clearing House demurrage regulations.

Canadian National Railways and Canadian Pacific Railway.

72 hours free time is allowed for a loaded car, after which a detention penalty charge of $1 a day, or part thereof, shall be made.

South African Railways and Harbours.

Traffic for shipment is allowed 7 days free storage at the port. 3 d. per ton for the next week and 3 d. per ton per day afterwards.

Landed cargo, 72 hours free; for the next 7 days, 3 d. per ton per day and any further period 1 sh. per ton per day.

Gold Coast Government Railways.

Loading. — 12 working hours are allowed, thereafter a charge of 15 sh. per vehicle per day, or portion of a day.

Unloading. — 12 working hours, with a minimum of 15 vehicles per day, thereafter a charge of 15 sh. per vehicle per day, or portion of a day, is raised.

Sudan Government Railways & Steamers.

24 hours free, after which demurrage is applicable.

New South Wales Government Railways.

On trucks of cement, coal, coke, iron or steel. In departmental wagons for direct shipment by sea, a period of 36 consecutive hours is allowed after arrival free of demurrage, after which a demurrage charge of 3 sh. 6 d. per day, or part thereof, on each four-wheeled truck.

Coke or coal in owners' wagons for direct shipment by sea will bear a charge of 1 sh. 9 d. per four-wheeled wagon per day, or part thereof, after the expiry of 36 consecutive hours after arrival at Darling Harbour.

North Western Railway, India.

Free loading time is allowed as follows :

At the merchants' storage platforms, private sidings, etc., 12 hours of daylight is given for loading or unloading.

Sundays and a few important holidays are regarded as dies non.

Demurrage is at the rate of one rupee per wagon for every three hours or fraction thereof in excess of the free time.

Wagons loaded within the port area with export cargo must be unloaded either :

a) 24 hours from the time the wagons arrive at the wharf, or

b) 36 hours from the time the wagons are supplied for loading.

Madras and Southern Mahratta Railway.

The question of demurrage does not arise as the work is carried out by the railway staff. Wharfage on consignments undelivered is levied after 5 days.

Ceylon Government Railway.

Traffic must be dealt with at once. There is no difficulty as there is often a shortage of wagons.

Federated Malay States Railways.

The Federated Malay States Railways demurrage regulations.

New York Central Lines.

City of New York Harbour :

Freight for export, except that moving on through bill of lading, is allowed 10 days free time.

When moving on through bill of lading 15 days is allowed.

Coastwise freight — 5 days.

Domestic lighterage — 48 hours.

Pennsylvania Railroad.

At Philadelphia :

The time allowed for loading and unloading, export and coastwise, freight is as follows :

Package or bulk freight.	15 days.
Except China clay.	5 —
Ore and pig iron.	48 hours.
Grain	20 days in storage.
Coal	5 days.
Domestic freight	48 hours.
Grain for reconsignment (in cars). . .	48 —
Coal — — . . .	48 —

At Sandusky :

Five days free time is allowed, after which a demurrage charge of $1.00 per car per day is made.

Port of New York :

Free time of 48 hours on domestic freight and 10 days on export freight is allowed, after which demurrage and storage charges are assessed in accordance with demurrage tariffs.

Norfolk and Western Railway.

On import and export traffic clearly indicated as such by owners, certain free times are granted to allow for interchange between ships and cars. If the free time is exceeded certain storage charges are assessed, based on weight, in lieu of demurrage charges applicable on a per car basis on domestic traffic.

Reading Company.

An average of 5 days for placing of vessels for cars on hand in yard. Demurrage charges computed on calendar month unloading basis, at $2.00 per day per car for detention in excess of 5 days free time allowed, plus Sundays and holidays.

Buenos Ayres Great Southern Railway.

For loading wagons from ships 24 hours are allowed, and for discharging wagons 48 hours.

Demurrage is charged on the expiry of these periods.

Buenos Ayres and Pacific Railway.

24 hours, calculated from 6-0 a. m. or 12-0 noon.

The port is allowed 48 hours, in a similar manner for the return of empty wagons to the Owner Company.

Japanese Government Railways.

The time limit for loading and unloading cars, for which the consignor is responsible, is six hours. For every 12 additional hours a demurrage charge of 50 sen per ton net weight of a car is imposed.

Railway Bureau, Government General of Chosen

Free time for loading and unloading : 2 hours for explosive materials and 6 hours for other materials, after which time notice is given and charges are imposed.

Demurrage is calculated on the net load of the wagon at 30 sen per English ton for every 6 hours or less after the expiration of the free time.

South Manchuria Railway.

As the Railway Company is responsible for the working, no such regulations are established.

Section II.

Tariff arrangements.

QUESTION 24.

a) *What are the general principles on which your special import and export tariffs are based?*

b) *In this connection, to what extent do the tonnage and frenquency of the traffic affect the tariffs ? (minimum weight, complete train loads, periodical or occasional).*

c) *To what extent do these tariffs take into consideration the origin of the traffic?*

London and North Eastern Railway.

a) and *b*) The import and export traffic is frequently carried at exceptional rates, particularly where the traffic passes with regularity and in large consignments.

c) Is not taken into consideration.

London Midland and Scottish Railway.

a) Schedules of maximum dues on vessels and on goods are fixed by Acts of Parliament authorising the construction of the docks. Labourage and cranage, etc. services are based on the cost of the work plus overhead charges and profit, and are variable according to the rise or fall of labour.

b) The tariffs are not affected.

c) To the extent only that dues on cargo to foreign countries are on a somewhat lower basis than those on cargo imported from foreign countries. Dues from coastwise cargoes are on a still lower basis.

Great Western Railway (Great Britain).

a) A charge per ton based on the value of the goods.

b) Quantity and frequency do not affect the charge.

c) Origin is not taken into account.

Southern Railway (Great Britain).

a) Based on costs, plus overhead expenses, risk and capacity of commodity to pay.

b) Special rates are applied to large quantities where a « straight run » from the ship can be arranged and direct loading performed.

Canadian National Railways and Canadian Pacific Railway.

a) Export and import rates are generally on a competitive basis as compared with alternative routes to world markets.

b) Export movements in volume of certain special commodities are granted export commodity rates.

c) If by origin is meant « National origin », there is no difference in the rate structure; if « distance » from a port is meant, the ton-mile rate is lower as the distance from the port increases, other factors being equal.

South African Railways and Harbours.

The remarks under this heading refer also to port of Durban. Import wharfage dues are based on tonnage and value of the goods, e. g. :

	Tonnage rate.	Ad valorem.
From Overseas	1 sh. 6 d. per ton.	16 sh. 8 d. per £100
» Coast ports	9 d. —	8 — 4 — —

With the exception of wool, hides, skins, angora hair, cotton, and scrap iron and steel, export wharfage dues are based on value only, as follows :

Coal; grain and bagged produce thereof; fruit, vegetables; sugar; bark; ores; eggs; butter; clay; asbestos; marble; concentrates	5 sh.	per £100 ad valorem.
Wool; hides; skins; angora hair	8 d.	per 100 lb.
Scrap iron and steel	1 sh.	per ton.
Cotton	6 d.	per 100 lb.
All other goods	10 sh.	per £100 ad valorem.

Sudan Government Railways & Steamers.

a) Quay dues are levied to meet maintenance charges; all the quays being 1/2 % and 1/4 % ad valorem on import and export cargo respectively.

b) No differentiation is made on account of either tonnage or frequency.

c) Not taken into account.

New South Wales Government Railways.

a) There are no special import and export rates so far as the New South Wales Railways are concerned, but to foster local industries special rates are levied on a number of commodities either grown or manufactured in the Commonwealth. These special rates are usually one class cheaper than the rate on the imported article.

c) Further percentage rebates and special rates are quoted for commodities exported beyond the State of New South Wales, so as to better enable manufacturers to compete outside the State; other than this the cheaper tariff rates do not take into account the origin of the traffic.

The principal items are; locally manufactured iron and steel; pig iron; galvanised iron; bacon or hams; wine; spirits; brooms; cheese; coal; dried fruits; cotton (ginned or unginned) pitch and tar; rice; soap; cement; asbestos slates and sheets; marbles; oils; crude residual, gas, gasoline, benzine, motor spirit, kerosene oil, machine oils, grease; shale oil.

The export items are : coal; iron and steel; cement, and wine.

North Western Railway, India.

a) The Railway has no special tariff for import and export traffic. Most of the goods traffic moves a considerable distance by rail and gets the advantage of the telescopic rates which apply equally to internal traffic.

In certain areas in which Bombay and

Karachi compete for the traffic, the rates to both ports are the same.

b) There are no special full train tariffs and no seasonal variations, nor are the tariffs affected by the tonnage or frequency. There are a few reduced rates for minimum weights.

Madras and Southern Mahratta Railway.

a) Import and export tariffs, i. e. wharf dues, are based on the cost of operations plus interest on the capital outlay, plus a reasonable profit, and are regulated according to the class of goods. In the case of ores a lower tariff is fixed equal to about half the lowest class rate.

b) Origin is not taken into account.

New York Central Lines.

City of New York Harbour :

a) Import and export rates are in effect proportional rates as the traffic does not stop at the port. Competition between countries and/or between the ports and volume of tonnage affect the rates.

b) Volume of tonnage is always taken into consideration whether export or import.

Pennsylvania Railroad.

a) Generally speaking export and import rates are the same as on domestic traffic, but in some cases they have been made lower to encourage movement, or to meet competition via ports not served by the railway, e. g. the Gulf ports.

b) These rates are generally the same as domestic traffic rates.

c) The tariffs ordinarily do not take into consideration the origin of the traffic other than that it must be either import or export, i.e. originating in or destined for a foreign country outside of North America where the lower export and import railway rates apply.

Baltimore and Ohio Railroad.

a) In general the tariff rates on the export and import traffic are the same as on domestic traffic moving to or from the port cities proper. Where export or import rates are lower than the domestic rates, the reasons are as follows :

1. Competition between carriers serving different ports which takes the form of depressed rates to and from the ports that will approximately equal the through rail and ocean charges maintained through another port.

2. To permit American manufacturers to compete with foreign manufacturers in the world markets.

3. To permit the rail carriers to compete with the all-water routes via St. Lawrence River, Welland Canal and Great Lakes.

b) The volume of traffic and frequency of movement are not determining factors, though in the making of any rates movement is encouraged.

The minimum weight per car in connection with import or export rates that are less than domestic rates is generally higher than on domestic traffic, so that in the final analysis the per car-mile earnings on the minimum car of import or export freight moving on the lower rates is generally as high or higher than on a minimum car of the same freight moving on the higher domestic rates.

c) The tariffs carrying export and import rates lower than the domestic rates are restricted in their application so that they will not apply on traffic to or from Canada moving by water, but there is no other distinction made as to foreign origin or destination.

Norfolk and Western Railway.

a) Cost of service, and competitive conditions, both traffic and industrial.

b) There are no periodical tariffs as such, minimum weight per car being the

only instance where tonnage affects the rates.

Reading Company.

a) Import tariffs based on fair return on investment, cost of operation, etc., taking into consideration depreciation.

b) Tonnage and frequency of traffic materially affects the tariff, as without complete train loads, regular movements, operating expenses would be much greater.

c) Tariffs, in every instance, are based on the length of haul, etc.

Buenos Ayres Great Southern Railway.

a) The import and export tariffs are based on the cost of handling (in labour) and expenses incurred by use of appliances.

b) Not affected.

c) Not affected.

Buenos Ayres and Pacific Railway.

a) No distinction made between tariffs for import and export.

Tariffs are based on kilometrage and divided into the following two classes:

Ordinary — consisting of 10 categories, and

Reduced — comprising 4 categories.

b) Reduced rates are applied for complete wagon loads and ordinary rates for general merchandise with fixed minimum loads between 100 and 10 000 kgr.

No special rates for complete train loads.

Classification according to article carried.

Grain, which is an important traffic, is classified at reduced rate.

Railway Bureau, Government General of Chosen.

a) Special import and export tariffs are adopted for certain kinds of freight and are for the protection of domestic industries.

b) The tariffs are not affected by tonnage or frequency.

c) The origin of the traffic is taken into consideration in fixing special tariffs.

South Manchuria Railway.

a) The Railway Company have no special import and export tariffs.

QUESTION 25.

a) *Are there direct tariffs between interior stations in your country and over-seas?*

b) *Do you have tariffs covering operations in addition to the placing of wagons on the quays?*

London and North Eastern Railway.

a) There are no direct tariffs except at Parkeston but, in many cases, a through rate will be quoted by combining railway conveyance at this side, sea, freight and rail conveyance at the other side.

At Parkeston there are direct tariffs, the Railway Company being the ship owners.

b) Yes.

London Midland and Scottish Railway.

a) The Railway Company do not quote such tariffs, but Shipping Companies using the port give quotations between Europe and interior towns via Garston.

Great Western Railway (Great Britain).

a) Direct tariffs between interior stations and overseas are in operation by various shipping lines.

b) Yes.

Southern Railway (Great Britain).

a) Various Shipping Companies issue through bills of lading from interior points in England to interior points overseas.

Canadian National Railways and Canadian Pacific Railway.

a) No. In certain cases through rates are quoted from United Kingdom ports to points in Western Canada.

b) Some tariffs cover delivery of goods *f. o. b.* cars at dock site, others *f. o. b.* dock, others *f. o. b.* elevators.

South African Railways and Harbours.

a) No.

b) Yes, export grain rates include a charge for placing in ships' slings.

Gold Coast Government Railways.

a) No.

b) Extra charge for use of cranes.

Sudan Government Railways & Steamers.

a) No.

b) There are no tariffs, but charges are raised for services rendered.

New South Wales Government Railways.

a) No.

b) There are additional tariffs covering other operations on wheat, coal and coke. A charge of 6 d. per ton on wheat is made for the use of appliances operated by the Railway Department at Darling Island for transferring wheat from cars or grain sheds to vessels. The following charges are made for the use of appliances for coal or coke shipping :

	Per ton.
Departmental wagons	10 d.
Owners' wagons :	
When loaded in single door hoppers	10 d.
When loaded in double door hoppers	11 d.
When loaded in box wagons .	1 sh.

North Western Railway, India.

a) Yes, to a very limited extent. Through booking of goods to Europe is restricted to consignments of wool and goat's hair full pressed in bales from certain stations and by certain firms only and to Liverpool only.

Goods may be booked through from Glasgow and Liverpool only via Karachi to 75 principal stations on the North Western Railway.

b) Yes.

Madras and Southern Mahratta Railway.

a) There are direct rates between interior stations and Bombay via Mormugao, but not to ports outside India.

b) Yes, hire and haulage charges and handling charges are levied when the traffic is not shipped direct from railway wagons.

New York Central Lines.

a) No.

b) Yes, terminal tariffs covering storage, demurrage, etc.

Pennsylvania Railroad.

a) There are no through joint rates between points in this country and overseas destination involving movement by vessel.

b) Tariffs cover operations other than the actual movement of cars on piers. For instance, under certain conditions, we assume in our road haul rate the cost of loading and unloading freight, and we also provide storage on our piers at certain specified rates for certain periods.

Baltimore and Ohio Railroad.

a) There are no tariffs covering through rates to or from foreign countries through the North Atlantic ports.

b) There are tariffs covering lighterage, storage, wharfage, and labourage on import and export traffic at the American sea board.

Norfolk and Western Railway.

a) No.

b) Yes.

Reading Company.

a) No.

b) Freight charges cover movement from originating point to port and include delivery of cars to vessel.

Buenos Ayres Great Southern Railway.

a) None.

b) There are different tariffs for loading and discharging vessels according to the class of cargo.

Buenos Ayres and Pacific Railway.

a) No direct tarifs between interior stations and overseas. Direct tariffs are applied to facilitate international traffic by rail between Buenos Ayres (Argentine) and Los Andes (Chile).

b) In no case do rates include operations on the quays.

Japanese Government Railways.

a) No.

b) No.

Railway Bureau, Government General of Chosen.

a) No.

b) There are additional charges covering operation of wagons on certain quay lines.

QUESTION 26.

What organisation do you favour in order to ensure that the wagons are placed at the disposal of the traders with the least possible delay, e. g. indication of the number of the quay on the invoice; advising the sending of traffic by telegram; sending the documents by express from the concentration yard to the different commercial offices, where they have to be checked before sending the arrival advice?

London and North Eastern Railway.

All the methods referred to, and others, are in operation. A very usual arrangement is to regulate the arrival of cargo by authorising senders to forward at a definite tonnage rate per day.

London Midland and Scottish Railway.

The shippers are, generally speaking, represented by Agents resident at Garston, and the whole of the formalities is conducted by such Agents who are in daily communication with the Dock Superintendent, who thus has timely notice of the arrival of vessels for export traffic.

The station is communicated with and arrangements made for the traffic to be worked through to meet the ship on arrival. The arrangements work satisfactorily.

The arrangements are such that the invoices are generally received either before or with the traffic.

Great Western Railway (Great Britain).

Merchants are advised immediately when wagons arrive with traffic. The other methods outlined are used when necessary.

Southern Railway (Great Britain).

Wagon label, the ship being indicated and prompt despatch of invoices when they are not placed on the wagons.

Canadian National Railways and Canadian Pacific Railway.

Present organisation satisfactory. Detailed means of communication include telegrams, messengers, postal service, and car tabs or cards. Export business is expedited by the use of forwarding agents who act as go-betweens between shipper, banks, railway, Port Authority, and steamship.

South African Railways and Harbours.

Invoices for forwarded traffic are despatched by train to arrive at receiving station prior to the arrival of traffic. When steamers are waiting for urgent traffic truck numbers are wired forward.

As all traffic is dealt with by the Administration no special advice is necessary.

Gold Coast Government Railways.

Telephonic advices of traffic sent by train control.

Sudan Government Railways & Steamers.

No organisation would be of service, nor is it called for. The berth of any ship is unknown until the vessel arrives. As this is not a terminal port the times of arrival cannot be ascertained with accuracy in advance.

New South Wales Government Railways.

The cars are ticketed with the name of the ship and the railway staff and Harbour Trust Authorities confer in regard to berthing. Ships and trucks are placed accordingly.

North Western Railway, India.

There is very little direct booking from up country to steamers, and exports are held in storage close to the wharf.

Madras and Southern Mahratta Railway.

Traffic is not generally loaded direct from railway wagons on arrival from up country. Wagons loaded from the stacking ground are labelled with special labels, indicating the names of the shippers, to facilitate sorting and placing alongside.

New York Central Lines.

Way bills shewing charges, etc. accompany shipment. On arrival of shipment at port terminal consignee usually advised by telephone or messenger, and in addition by U. S. mail.

Pennsylvania Railroad.

At Philadelphia :

Cars are moved to destination on the revenue waybill, which carries complete information as to the character of the shipment, to whom consigned and the charges to be collected thereon. Waybills are delivered to the Freight Agent's office immediately upon arrival of the cars, and the proper notification is promptly sent to office of the connecting steamship line, the cars being held for delivery orders. When the latter are received the Agent then gives the necessary instructions to the Transportation Department to have the cars placed on the pier either for unloading to pier or for direct delivery to the vessel.

At Sandusky :

It is customary to handle all waterborne traffic at a given City through one Freight Agent, to whon all orders from patrons are addressed and the freight is forwarded to his station with an indication of the steamship line for which it is intended.

At Port of New York :

Steamship booking space is usually arranged after arrival of the freight at the terminal yards and indication of the quay on invoices or notification of traffic by telegram would serve no purpose. Upon arrival of the car at the terminal,

notice is sent to the consignee who, in turn, lodges dispositon orders with the lighterage agent of the Railroad Company. On short time orders it is customary to telephone them from the rail termini to the lighterage organisation who, in turn, furnishes a marshalling order to the yardmaster followed by written delivery orders to the yardmaster between the Commercial Office and the port quays. The order to the yardmaster designates the pier at which the cars are to be placed and the lighters are moved according to the position of the cars on the pier.

Baltimore and Ohio Railroad.

The consigning of import shipments in care to the Foreign Freight Agent representing the Railroad at the American port of arrival is favoured. Export traffic should be consigned in care of the steamer line for which intended and plainly marked « for export ».

Norfolk and Western Railway.

A combination of all the items mentioned and is entirely satisfactory.

Reading Company.

An arrangement that assembles all data for the information of traders, shippers, etc. with the least possible delay is favoured. This is done by U.S.A. mail invariably, with retention of full and complete mailing record for assembly of freight bills, demurrage records, etc., frequently by telephone with confirmation via U.S. mail.

Buenos Ayres Great Southern Railway.

Consignees generally arrange with senders to advise them by telegram of the despatch of traffic to a ship. On its arrival at the concentration yard the Station Agent communicates with consignee by telephone, confirming this in writing by special messenger.

Buenos Ayres and Pacific Railway.

If traffic is destined for shipment abroad or delivery at Port, the loader gives the following details on consignment note :

a) Name of ship or warehouse.

b) Number of dock.

c) Loading side of dock.

The same information is given on a way-bill.

All wagons are detained when addressed to the ship or installations not in a position to accept. Information for this purpose is obtained daily from the port and advice immediately passed on to consignee who re-addresses traffic which then continues to destination.

Japanese Government Railways.

The consignor has to present the consignment note to the Railway Company the day before the wagons are required, and the wagons are placed accordingly. The detailed practice differs at each port.

Railway Bureau, Government General of Chosen.

The following measures are taken :

The number of the line on which freight is unloaded is shewn on the car label.

Notice of arrival is given to the consignee by telephone before placing the cars for unloading.

If consignor does not unload within the time limit the Railway Company discharge the car.

South Manchuria Railway.

The Wharf Office undertakes the following duties :

1. Arranges the working in the wharf precincts.

2. Makes tariff arrangements.

3. Arranges for transhipment.

4. Marshals inward and outward wagons.

5. Engages labourage.

6. Makes the coaling arrangements.

Instructions are issued to the executive officers to suit the convenience of the traders.

QUESTION 27.

Have you any suggestion to make with reference to the organisation of the Customs Service, with a view to making better working arrangements to meet the needs of the Railway Company?

English Railways.

No.

Canadian National Railways and Canadian Pacific Railway.

No.

South African Railways and Harbours.

No suggestion. Harmonious working prevails.

Sudan Government Railways

No.

New South Wales Government Railways.

No.

North Western Railway, India.

The present system of discharging cargo direct into railway cars and removing them to the import yard is inefficient, and much time is lost in tallying the goods between ship and wagon and in examining damaged goods. Transit sheds and bonded and open warehouses on the wharf would overcome this difficulty and save much handling and haulage.

Madras and Southern Mahratta Railway.

No.

Ceylon Government Railways.

No.

Federated Malay States Railways.

Office hours should most certainly synchronize and an official with necessary powers should be in attendance the whole time the office is open.

New York Central Lines.

No.

Pennsylvania Railroad.

Arrangements are in general satisfactory.

Baltimore and Ohio Railroad.

No.

Norfolk and Western Railway.

No : present organisation is satisfactory.

Reading Company.

Customs service is very rarely used. Practically all business is domestic.

Buenos Ayres Great Southern Railway.

The customs service should be organised so that the necessary fiscal control of the merchandise may be carried out without delay to rolling stock.

Buenos Ayres and Pacific Railway.

Customs do not affect the Railway as negociations are carried out by parties interested in the traffic.

Japanese Government Railways.

Much better working could be obtained if the office hours of the Customs House were altered.

Railway Bureau, Government General of Chosen.

No.

South Manchuria Railway.

No.

QUESTION 28.

Do you take special measures in order to reduce the time needed for the formalities in connection with the delivery of goods for export (information as to arrival, payment of freight; delivery of invoices, etc.)?

London and North Eastern Railway.

The ordinary arrangements are effective and no difficulty is experienced.

London Midland and Scottish Railway.

The arrangements are satisfactory and difficulties rarely arise.

Great Western Railway (Great Britain).

All precautions are taken by way of preliminary arrangements.

Southern Railway (Great Britain).

No, the procedure of advising shipping of arrival and labelling of wagons to a specific ship works admirably. Correct and adequate wagon labelling is the essential factor.

Canadian National Railways and Canadian Pacific Railway.

A Foreign Freight Department of the Railway Company specializes in this service, and by co-ordinating activities and expediting the completion of documents, facilitates movement of export and import business.

South African Railways and Harbours.

No.

Gold Coast Government Railways.

Advice is sent of goods for known consignees when available for delivery at export quay immediately on arrival.

Sudan Government Railways & Steamers.

No, not necessary. Notice of export tonnage is obtained in advance and goods are in position for loading either in wagon or at dump before the arrival of export ship.

New South Wales Government Railways.

The bulk of traffic for export is dealt with by firms with guaranteed freight accounts with the railway. If any consignments for consignees without guaranteed accounts, delivery porters notify the Accounts Branch of the Department, who arranges for payment of freight by consignees concerned.

North Western Railway, India.

Every endeavour is made to expedite the handling and despatch of export traffic.

Madras and Southern Mahratta Railway.

There is no delay.

Federated Malay States Railways.

Resident Agents are advised by telephone if necessary to facilitate and hurry up customs requirements.

New York Central Lines.

Teletype machines are used between concentration yard freight office and marine department lighterage office.

Pennsylvania Railroad.

At Philadelphia :

In some special instances information of the arrival of traffic is telephoned to the connecting line office, but in most cases it is forwarded by messenger at frequent intervals. The payment of freight charges is very generally handled upon an accommodation list basis, which provides 48 to 96 hours credit for payment. The delivery of invoices, etc. is usually handled by express.

At Sandusky :

No difficulty is experienced. Usually shippers forward to the seaboard in sufficient time to deliver to the vessels without difficulty.

At Port of New York.

When necessary orders are received and given by telephone and consignee notified of the arrival of traffic by telephone and confirmed in writing.

Baltimore and Ohio Railroad.

Export property is classified or segregated in the terminal yard, as far as possible, for the steamer lines for which intended and held there subject to their call.

Norfolk and Western Railway.

Yes.

Buenos Ayres Great Southern Railway.

No delays incurred.

Buenos Ayres and Pacific Railway.

Grain constitutes an important item of export traffic and delivery formalities at the port do not cause delay as traffic is consigned to responsible firms with current accounts, the presentation of invoice only being required.

Railway Bureau, Government General of Chosen.

No.

South Manchuria Railway.

No special measures are taken.

[621 .133 .7 (.73)]

Chicago and Alton checks corrosion in locomotive boilers.

Figs. 1 to 5, p. 2368 to 2372.

(*Railway Age.*)

Since September 1924, the Chicago and Alton has equipped the boilers of 75 locomotives with an electro-chemical method of preventing boiler corrosion, known as the Gunderson process. This method, first developed on the Alton, consists of introducing a compound of arsenic into a boiler, equipped with electrodes which permit passing electric current through the water to the interior metal surfaces of the boiler and thus create a condition inhibitive to pitting and grooving. The arsenic compound is put into the boiler in one-pound tubes through one of the washout holes. The electric current is obtained from the headlight generator or from a storage battery connected with it.

Alton water treated to reduce hardness.

The satisfactory results of over four years' tests, most of them conducted under the direction of C. M. House, superintendent of motive power and equipment, have caused the Alton to make this equipment standard for application to all locomotives as they receive general repairs. These results are summarized by officers of the road, as follows : Practical elimination of corrosion in the boilers equipped; general increase in tube and flue life from 12 months or less to the four-year limit set by the Interstate Commerce Commission requirements; firebox life proportionately increased, with substantial reduction in boiler maintenance costs and locomotive out-of-service time; and the practical elimination of engine failures due to pitted tubes and flues, with the attendant irritating and costly service delays.

Most of the raw waters available for locomotive use on the Chicago & Alton carry a high content of mineral salts, as shown in one of the tables, the total hardness in the worst case, namely, that of the Bloomington city water, being 54.3 grains per gallon. By 1924, automatic soda-ash plants had been generally installed to prevent the formation of hard scale on boiler tubes and firebox sheets. The specific treatment given the Bloomington city water was to supply 4 1/2 lb. of soda ash per 1 000 gallons with the object of completely neutralizing the sulphate hardness and leaving a surplus of sodium carbonate. Of two other waters available for locomotive use at Bloomington, the Illinois Power & Light water was treated with two lb. of soda ash per 1 000 gallons and the water from the Big Four well with 1 3/4 lb. per 1 000 gallons.

By this method of treating boiler feedwater, the difficulties due to scale formation were largey solved, but boiler pitting grew worse. Yard locomotives at Bloomington, Ill., for example, sometimes required almost two full sets of tubes and flues for each machinery shopping, boiler sheets and staybolts deteriorating likewise. A total of 7 800 tubes were scrapped in back shops because of pitting and grooving during a period of a little more than a year, and in addition during the same period, there were 556 instances of tube failures. Expensive delays chargeable to these failures made

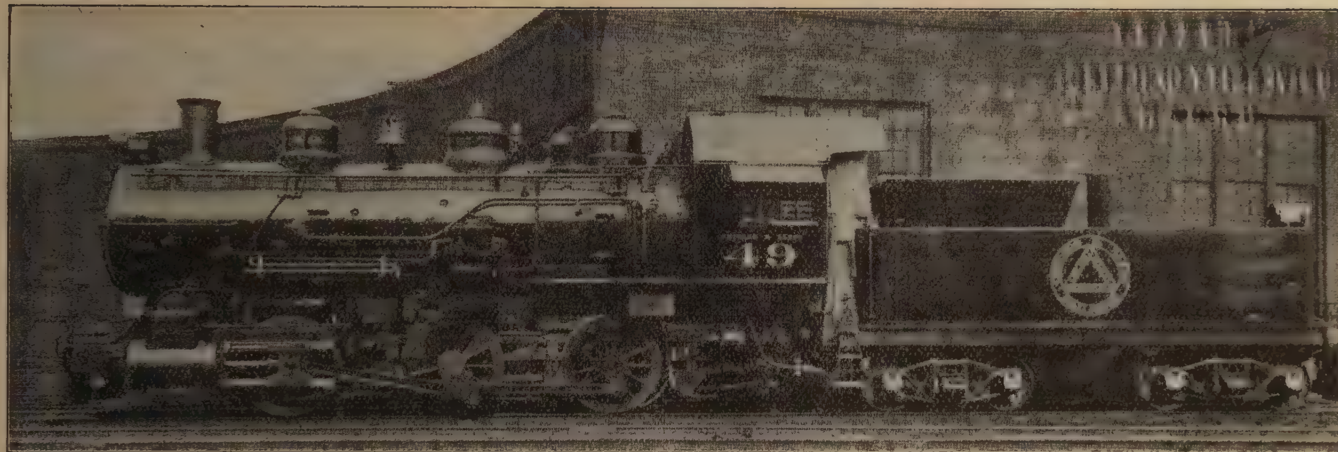


Fig. 1. — The first Chicago & Alton locomotive to be provided with Gunderson process equipment for preventing corrosion.

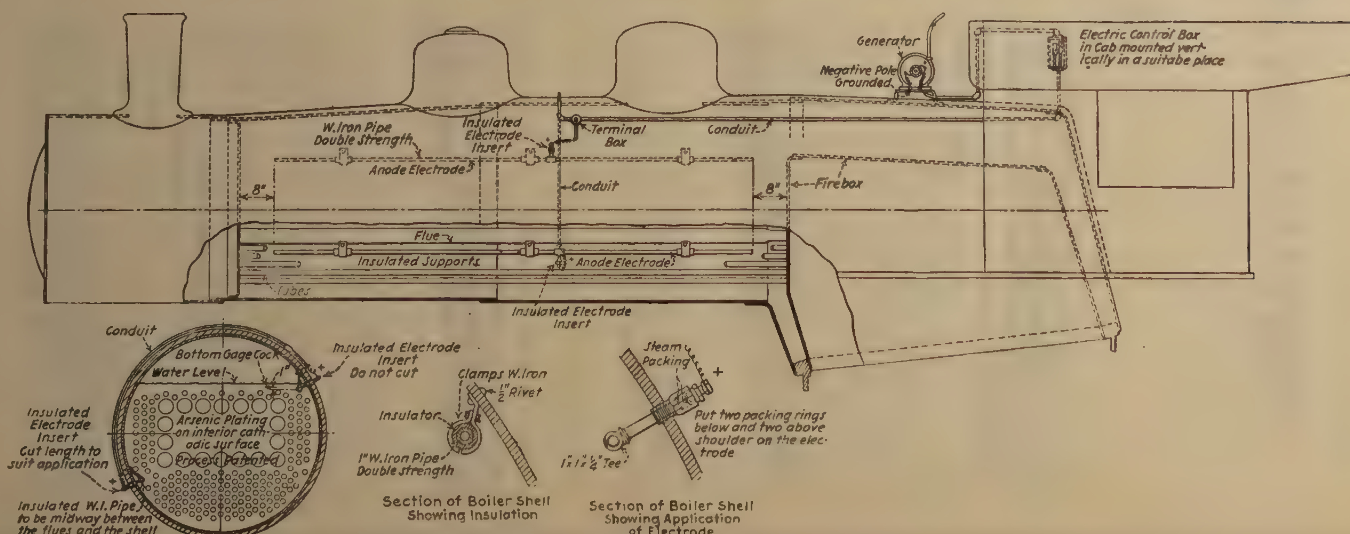


Fig. 2. — Details of application of Gunderson process equipment to a locomotive boiler.

it imperative to check corrosion, and, in 1924, it was decided to equip test locotives with the newly-developed process.

Operating results and savings.

Installations of the Gunderson process to Chicago and Alton locomotives were made as follows : 2 in 1924; 2 in 1926; 17 in 1927; 40 in 1928; and 14 in 1929 (up to 15 March). It is impossible to give a definite statement of savings from the prevention of pitting and corrosion in the 75 boilers involved, because of the large number of indeterminate factors, such as the savings in boiler material, labor, locomotive out-of-service time, locomotive failures, train delays, etc. Some idea of what has been accomplished, however, may be obtained by analyzing the results in one or two specific cases.

Locomotive 49, for example, the first to be equipped, in September, 1924, is a six-wheel switcher, used in the same yard service at Bloomington, Ill., as locomotive 44, non-equipped. A Pacific-type locomotive, No. 656 and a ten-wheel locomotive, No. 251, used in fast passenger service on the Northern and the Western divisions, respectively, were equipped with electrodes in October 1924, and March, 1926, respectively, locomotives 658 and 254, non-equipped, being operated in similar service.

Analysis of raw water supplies (expressed in grains per gallons*) at principal water stations on the Chicago & Alton.

Location.	Source.	Total hardness.	Carbonate hardness.	Sulfate hardness.	Alkali salts.	Dissolved solids.
Kansas City	City water	17.0	10.5	6.5	6.4	23.4
Blue Springs	Pond	10.2	7.6	2.6	10.3	20.4
Odessa	Pond	9.8	5.3	4.5	4.4	14.1
Blackburn	Pond	9.6	4.7	4.9	5.5	15.1
Slater	Pond	9.2	2.9	6.3	16.2	25.3
Glasgow	Mo. River	12.2	8.2	4.0	13.4	25.6
Higbee	Pond	6.7	2.9	3.8	7.7	14.4
Larrabee	Pond	2.8	0.6	2.1	3.4	6.2
Mexico	Pond	8.2	3.5	4.5	8.4	16.8
Booth	Pond	6.9	4.1	2.8	10.0	16.9
Louisiana	Miss. River	12.0	8.4	3.6	2.0	14.0
Pearl	Ill. River	15.6	10.5	5.2	14.8	20.4
Roodhouse	Spring	19.4	16.3	3.0	1.4	20.8
Brighton Park	Chicago water	9.0	7.0	3.0	0.1	9.1
Glenn	Canal	11.5	7.6	4.0	22.8	34.4
Braidwood	Well	21.0	18.1	2.9	15.7	37.4
Mazonia	River	19.2	12.8	6.3	7.6	26.8
Pontiac	River	22.3	15.2	6.2	11.4	32.7
Bloomington	City water	52.2	23.6	28.6	16.8	69.0
	**I. P. L. well	42.5	28.9	13.6	6.0	48.5
	Big Four well	37.8	28.9	8.9	9.0	46.8
Ridgely	River	10.5	7.0	3.5	9.5	19.6
Springfield	City water	7.2	2.3	4.9	5.8	12.9
Virden	Pond	17.1	10.5	6.7	3.0	20.1
Rinaker	Pond	4.2	2.3	1.8	3.3	7.4
Godfrey	Pond	11.7	8.2	3.5	6.8	18.2
Venice	City water	10.3	7.0	3.3	5.5	15.7

* Multiply by 1.72 to convert to parts per 100 000. ** Illinois Power & Light.

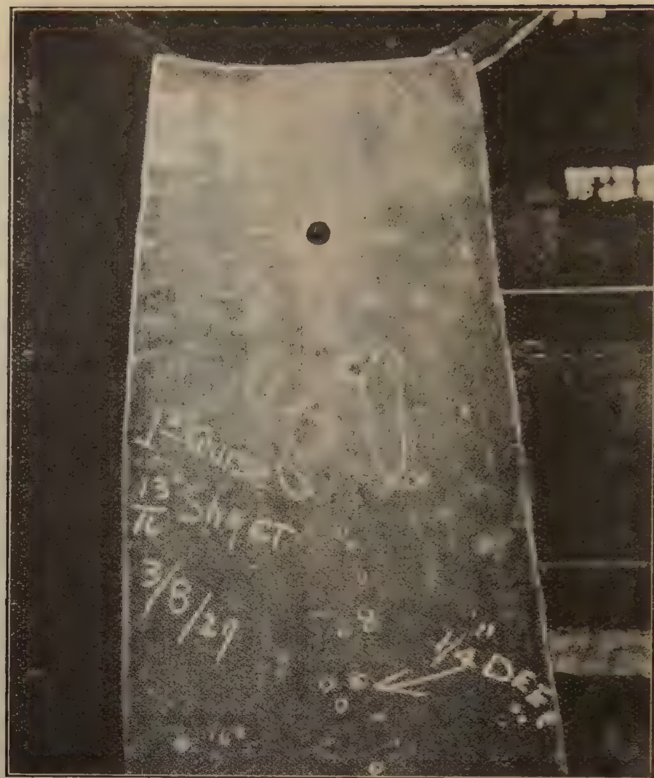


Fig. 3. — Close-up view showing pitted condition of the belly sheet cut from the first course of the boiler of locomotive No. 44.

Fig. 4. — A sheet metal box under the running board houses special equipement including the storage battery when used to obviate running the headlight generator during daylight hours.

A comparison of the service records of these locomotives will give a measure of the effectiveness of the electrode applications, since to as large an extent as possible other variables have been eliminated. There has been no change, for example, in the kind of boiler tube material used on the Alton in recent years. While these locomotives have not all taken water from the same source, all have used water which promotes corrosive action to a greater or less extent. There has been no change in the method of blowing off or washing boilers since the installation of the process. The inbound and outbound method of blow-off is utilized on passenger power accompanied by restricted blow-off on the road. The inbound and outbound blow-off is also used with switching power, accompanied by occasional blow-offs in the yard.

Corrosion eliminated in locomotive 49.

Detailed boiler-shopping records of locomotives 49 and 44 are shown in two of the tables. Within a period of three years and two months before the installation of electrodes, locomotive 49 had been through the back shop on two different occasions for retubing and general overhauling necessitated by pitting and grooving. Previous to the shopping in September, 1924, approximately 100 tubes had been removed in the enginehouse due to failure through pits, and, while in the shop, 213 more pitted tubes were scrapped with an estimated loss in tube material alone of $595. The electrodes were installed in the boiler at this shopping period. The boiler was then shopped in July, 1926, principally for an inspection to determine the completeness with which corrosion had been prevented. The steel tubes were removed, found free from pits, and reapplied to another boiler, and 283 new steel tubes were applied to the boiler of locomotive 49. Other parts of the boiler were also found to be free from corrosion. At the next shopping in February, 1929, after making 50 925 miles, an interior inspection showed the boiler to be free from corrosion as far as inspection could disclose. Consequently, the tubes were not removed but were left to run the full four years allowed under Interstate Commerce Commission regulations.

Locomotive 49 boilers. Shopping record.

(Electrode-equipped.)

Classification : 0-6-0.

Number of tubes and flues :
 283 tubes, 2 inches by 12 ft. 8 in.

Class of service :
 Switching service in Bloomington yards.

Condition prior to 1924 shopping :
 Pitted tube failures common, sometimes occurring daily.
 Approximately 100 failures since previous shopping in June, 1923.
 Newly applied firebox sheets and staybolts.

Boiler shopped, 24 September 1924 :
 283 second-hand steel tubes applied.
 213 old tubes scrapped on account of pitting.
 210 new staybolts applied.

Gunderson process electrodes installed.

Date of first tube failure—None.

Boiler shopped, 21 July 1926 :
 Tubes removed, found free of pits, safe-ended and reapplied to another boiler; 283 new 2-inch tubes applied.
 New right side sheet, 7 rows high, applied.
 Considerable other boiler work, done at this shopping, was not due to corrosion.
 Locomotive stored empty for 3 months, but small rust spots developed on the tubes; did not have characteristics of pits.

Date of first tube failure—None.

Boiler shopped, 20 February 1929—50 925 miles :
 Lagging taken off to permit removal of flexible staybolt caps.
 Not necessary to remove tubes.
 Interior inspection showed good condition with no signs of pitting.

Date of first tube failure—None.
 Will get at least 4 years' service with these tubes and extension may be requested.

The record for locomotive 44 shows that when it was shopped in December, 1926, practically all of the full set of 283

Fig. 5. — View showing upper electrode pipe and early method of insulating and supporting it.

tubes was scrapped on account of pitting. The front tube sheet was pitted and grooved, requiring renewal, as well as the bottom half of the second course. After nine months' service, or in September, 1927, a pitted tube was replaced and from that time until 2 March, 1929, or in 18 months, a total of 238 pitted tubes were replaced in this boiler at 60 different times. Replacements were made in the enginehouse as the tubes failed or when inspection disclosed leaks through pits. At the shopping in March, 1929, 145 pitted tubes were scrapped, even though all but 45 of the full set of tubes had been replaced since December, 1926. It will be noted that during this period of two years and three months while making 43 784 miles, 383 pitted tubes were scrapped, representing a loss in material (at 15 cents per foot of $727, to which must be added a minimum enginehouse labor cost of at least $5 for each of the 60 failures, bringing the total loss due to pitted flues to $1 027. It was also necessary to renew the front tube sheet and belly sheet of the second course on account of pitting.

Locomotive 44 boiler. Shopping record.

(Without electrode equipment.)

Classification : 0-6-0.
Number of tubes and flues :
  283 tubes, 2 inches by 12 ft. 8 in.
Class of service :
  Switching service in Bloomington yards.
Condition of boiler :
  Safe-ended tubes in good condition.
  No electrode equipment.
Boiler shopped, 6 December 1926 :
  283 tubes removed, safe-ended and reapplied on account of pitting.
  Front tube sheet renewed on account of pitting.
  Bottom half of second course renewed for some reason.
Date of first tube failure :
  9 September 1927.
  Total of 238 tube failures up to 2 March 1929.
Boiler shopped, 5 March 1929—43 784 miles.
  283 tubes removed, 145 being scrapped on account of pitting.
  New half belly sheet, first course, applied on account of pitting.

The effectiveness of this method of preventing corrosion has been strikingly demonstrated at the Bloomington enginehouse for the reason that switching locomotives 44, 64, 65 and 412, not equipped continue to give trouble, due to the failure

of pitted tubes, thus requiring extra work in the enginehouse and frequently delaying switching service in the yards. Locomotive 49 has never had a flue failure since coming from the shop in 1924, and the flues are in good condition at the present time.

Grooving of tubes at front flue sheet stopped.

Locomotive 656, in fast passenger service between Chicago and Bloomington, had several tube failures previous to the 1924 shopping due principally to grooving at the front sheet. In October, 1924, it was necessary to scrap 175 pitted steel tubes and 19 superheater flues, approximating a total loss of $ 898 in material. A pitted and grooved front flue sheet was renewed, and grooves in the belly were patched. The Gunderson process, with only one electrode above the flues, was applied to the locomotive at this shopping, whereas locomotive 49 had received two electrodes.

In July, 1926, after having made 112 000 miles, the locomotive was again shopped for general overhauling, at which time only the tubes below the superheater flues were removed for inspection. This inspection disclosed the fact that the use of arsenic at about six months intervals was insufficient, and that the experimental voltage of 17 volts was excessive, inasmuch as a few bottom tubes farthest from the anode were found to be slightly pitted. However, all of the tubes removed were safe-ended and reapplied to another boiler. The balance of the boiler was free from pitting or grooving. It was decided to continue the use of the single electrode, but to add arsenic semi-monthly and use between 2 and 3 volts, as tests on locomotive 49 indicated this to be more effective. At the next shopping in November 1928, after making 150 000 miles, all of the tubes and flues were renewed, safe-ended and reapplied, and the balance of the boiler was found free from corrosion. Of special interest was the fact that the grooving of the tubes at the front flue sheet, so prevalent in this class of locomotive, was entirely prevented. At this shopping the latest type of double electrodes were applied.

Locomotive 658, of the same class as No. 656 and in the same service, was shopped in December, 1925, at which time 155 tubes were scrapped due to being pitted and grooved; 155 new tubes and 55 safe-ended tubes were reapplied. In July, 1927, after 19 months of service, the locomotive was in the shop for light repairs, at which time no flues were removed. On 4 February 1929, the boiler entered the shop and 30 tubes were scrapped on account of pitting; also, the first and third courses and bottom half of the second course were pitted, requiring renewal. Other locomotives of this class might be mentioned. Locomotive 621 had three flue shoppings within a period of four years and eight months with a recorded loss of $ 965 due to scrapped, pitted tubes. Locomotive 625, in making 110 000 miles, developed, according to the master mechanic's report, 26 different tube failures, involving 94 pitted tubes, resulting in a loss of material of over $ 300.

Locomotive 251, operating between St. Louis and Kansas City, with its home terminal at Slater, Mo., was equipped with electrodes at the regular shopping in March, 1926, when the majority of the 288 tubes were scrapped because of pitting. At the same time, 178 grooved staybolts were renewed, and inspection showed the side sheets to be grooved but not seriously enough to require renewal. After three years of service, making a total of 108 744 miles without a tube failure, the boiler was again shopped in March, 1929, and found free from pitting, with one exception. The bottom electrode was discovered to be short circuited, and 30 tubes adjacent to it were pitted, 3 of them being scrapped. Locomotive 254, without the electrodes, had

225 pitted tubes renewed in the engine-house previous to being shopped in September, 1927, when 93 additional pitted tubes were scrapped, making a total of 318 scrapped tubes caused by pitting during the time the locomotive was making 118 000 miles. The cost of the replacement tubes amounted to $ 760. Inspection showed the front flue sheet, firebox sheets and a large number of staybolts to be seriously grooved, requiring renewal, no estimate being made of the cost of material for this work.

How the Gunderson process works.

The mechanism of boiler-metal corrosion, which the new process is designed to counteract, may be described as follows : The surface characteristics of boiler metal are never uniform, and, therefore, certain small areas have a greater electric potential or tendency to dissolve than other adjacent areas, these variations in the surface of the metal in effect acting as tiny batteries, wherein small electric currents are produced by solution of the iron as it forces hydrogen-ions to be deposited on the low potential surfaces. All boiler metal is inherently subject to this destructive electrolytic action, but only under certain water conditions. The solution of iron in the boiler water is accomplished by the iron forcing out hydrogen-ions and then uniting with the remaining portion of the water molecules to form iron hydrates. These hydrates react with oxygen to become oxides, some of which accentuate electrolytic action, thus explaining why pitting penetrates the boiler tubes and flues rapidly, once it gets started.

If mill-scale (iron oxide), for instance, or some other substance having a like low potential, is in contact with the iron surfaces, hydrogen is deposited much more easily and the iron is corroded faster. Any strain, resulting from cold working of the metal, or vibration in road service, increases the solution pressure or electric potential of the stressed portions and causes these portions to corrode in preference to the adjacent metal on which the hydrogen is deposited. The deposit of hydrogen on the boiler metal surface as a thin invisible film, however, effectually hinders and finally entirely prevents the deposit of additional hydrogen, and no more metal can dissolve until the hydrogen is removed by some agency. This is accomplished by dissolved oxygen in the boiler feedwater which proves effective in removing the hydrogen film by combining chemically with it to form water. The real function of the Gunderson process is to maintain this film of hydrogen, producing a state of polarization like that found in batteries.

The new process sets up a protective condition on the interior surfaces of the boiler by means of an arsenic plating on which hydrogen is deposited and tenaciously retained. Two insulated iron-pipe electrodes are installed in the boiler, and an electric current of about four or five amperes at two volts from the headlight generator (or storage battery) is passed through the boiler water from these electrodes (anodes), the boiler metal being the negative pole of the circuit. A commercial chemical compound of arsenic is dissolved in the boiler water, from which the arsenic plates out on the boiler metal. The arsenic not only has the characteristic of retaining the hydrogen film but neutralizes the inequalities of solution pressure or electric potential which cause the localized action on the surface of the boiler metal.

Method of installation. — Operating cost.

The arsenic alone, without the electric current, is said not to be effective because the film on the interior boiler surfaces is soon destroyed by chemical combination with the dissolved oxygen in all boiler feedwaters. The electric current, without the arsenic, will not prev-

ent localized corrosive action which takes place just as on battery plates.

The installation is made substantially as shown in the drawing. The electrode stuffing boxes are usually located for convenience in the third course of the boiler shell.

If the tubes and flues are in the boiler when the installation is made, both anode pipes are placed above the tubes on opposite sides of the shell. If the tubes and flues are out of the boiler when the installation is made, the anode on the left side is located above the flues and the one on the right side is located diagonally opposite the first. Each anode is spaced equidistant between the shell and the flues. The clamp supports are assembled so as to grip snugly the insulating tubes which are placed around the 1-inch anode pipes. Metallic contact of the anode pipes with the boiler structure is avoided as this would short circuit the system. The positive pole of the generator is connected to the insulated electrodes and the negative pole is grounded at the generator. The generator voltage is cut down to two volts by means of suitable resistance coils placed in the electric circuit, these coils being carried in a control box which also contains necessary fuses and an ammeter to show when the system is working. The control box is located at a point in the cab where it can be readily seen by the engineman. The storage battery and auxiliary equipment, when used, is located in a suitable steel box under the running board. Before putting the locomotive in service, sealed cylinders, containing five pounds of the polarizing chemical (a soluble arsenic compound) are placed in the boiler through a washout hole; thereafter a one pound cylinder is applied at least twice a month.

Little maintenance expense.

Owing to the simplicity of the apparatus, there has been practically no maintenance expense for the Gunderson process applications on Chicago & Alton locomotives. The installations are checked by electricians at each monthly locomotive inspection to determine if the wiring, fuses and resistance units are in good operating condition and if the electrodes are thoroughly insulated. The operating expense incident to the use of the process includes the cost of electric current (about 128 watts) taken from the headlight generator, the cost of arsenic compound, and the cost of replacing the anode pipes once in four years at the limit flue-shopping period. The iron pipe anodes disintegrate or waste away, but ordinarily have a service life of at least four years.

Operating cost is low.

The cost of the protective current when the turbo-generator is being run to furnish current for the locomotive lighting system is 0.6 cent an hour. With the battery installation, charging being accomplished direct from the generator during the time the latter is normally in operation, the cost of electric current is silghtly higher. When lights are not necessary and the generator must be run to supply current for the electrodes alone, the cost is about 2.5 cents an hour. These costs, of course, vary with the efficiency of the generator and the cost of fuel. The annual cost of current per locomotive can easily be calculated from these figures when the approximate number of night-hours and daylight-hours a locomotive is in service is known. For average operation of a road locomotive, the annual cost is approximately $15.00.

The cost of arsenic compound, already prepared in individual tubes for application to the boiler, is 15 cents a pound. It is the practice on the Alton to apply one pound every 15 days, irrespective of water changes, so the cost of compound for each locomotive equipped amounts to 30 cents a month or $3.60 a year.

[625 .111 (.73)]

How New York is eliminating its grade crossings.

Figs. 1 to 3, p. 2377.

(From the *Railway Age.*)

As the grade crossing problem has become more serious from year to year, owing to the rapid development of the country, the phenomenal increase in highway traffic, and the increased frequency and speed of rail traffic, municipal, county and state officers and public regulating bodies over the country have attempted to cope with the situation to various degrees, in various ways and with widely varying degrees of success. A few states, through various methods, are beginning to make some progress in the solution of their grade crossing problem, but the one state which is apparently making the greatest progress in the elimination of its grade crossings, is New York. Under the present policy of that state, a number of measures have been adopted to insure a progressive program of grade crossing elimination work, to provide for financing the work through assistance by the state, and to preclude unnecessary delays in carrying out the work.

New York has a larger motor vehicle registration than any other state, totaling 2 083 942 in 1928. It also has approximately 7 371 grade crossings of main tracks at the present time outside of the city of New York. Viewed from another angle, the seriousness of its problem may be appreciated through the fact that from 1 January 1925 until 1 August 1928, a total of 632 major grade crossing accidents occurred in the state, of which 321 involved fatalities. In the first eight months of 1928 alone, 47 fatal and 67 non-fatal accidents occurred at grade crossings in the state.

First grade crossing laws in 1897.

Since 1897, laws have been on the statute books of New York relative to the elimination of grade crossings. From the standpoint of the necessity of eliminating the relatively few grade crossings which might have been considered to be unusually dangerous in the early years of the present century, these laws appeared adequate, but by 1920 agitation had become pronounced for more action than was possible under the laws then in effect.

Under the old statutes with respect to the elimination of grade crossings, which were embodied in what is known as the Railroad law, relatively little was accomplished from the standpoint of eliminating ultimately the major part of the grade crossings of the state. Definite provision was made in this law whereby the railroad companies would pay 50 %, and the state and the municipalities each 25 % of the cost of grade crossing elimination projects, but the inactivity of this provision is seen through the fact that the last appropriation made by the legislature was in 1923 when only $500 000 was appropriated to cover the state's share. Prior to that time appropriations were generally for $100 000 but in several years no appropriation at all was made.

Possibly the greatest obstacle in the

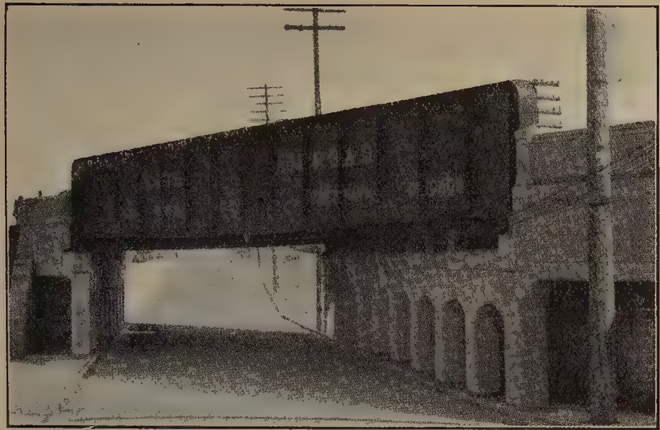


Fig. 1. — A multiple-track overhead crossing on the Erie Railroad at Jamestown, N. Y.

Fig. 2. — Where the New York Central crosses the Kirkland-Rome county highway at Clark Mills, N. Y.

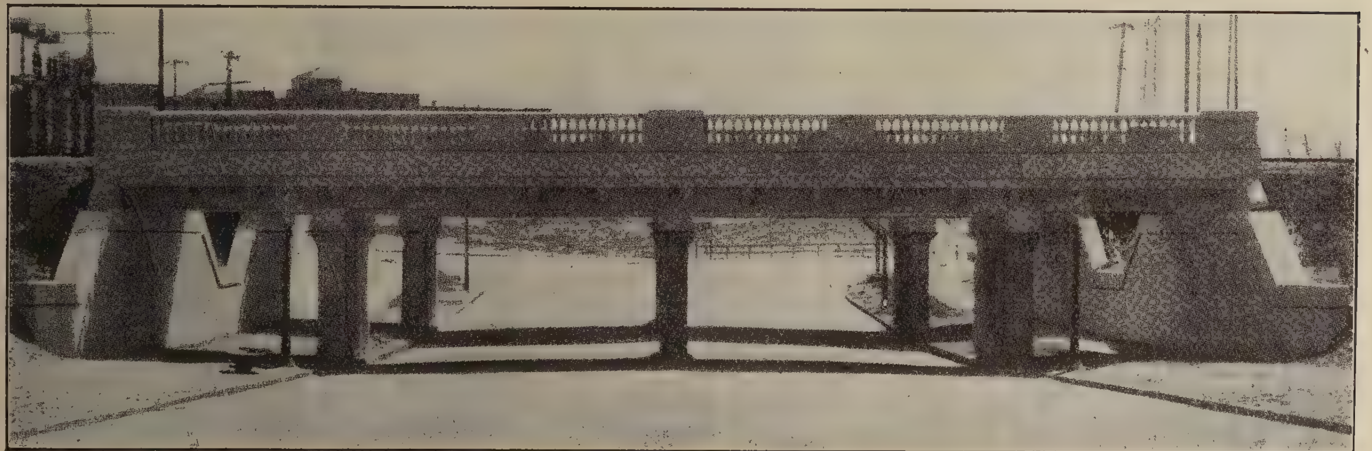


Fig. 3. — An attractive overhead crossing of the Erie and Lehigh Valley at Rochester, N. Y.

way of eliminating grade crossings within the state, was the lack of funds available for this work. There was no statutory requirement that the legislature should appropriate any amount, and therefore, in making appropriations, it was governed largely by the balance which the Public Service Commission had available with which to order eliminations. Under the law, the commission could not make an order directing an elimination unless funds with which to pay the state's share had been appropriated prior thereto.

In addition to the sums appropriated by the legislature for specific use by the Public Service Commission in paying the state's share of the cost, there was one other source from which money could be had for this work. This source was certain funds of the Department of Public Works, then known as the Commission of Highways, and while these funds were greatly limited, there were several years when it was possible to eliminate crossings only because of the fact that money was available from this source.

Disastrous accident brought about new laws.

Laboring under these difficulties, relatively little was accomplished and agitation for elimination work was limited to localities interested primarily in special projects. This condition might have continued for some time under normal conditions except for a grade crossing accident in 1923, in which 9 people were killed and 30 were injured. The feeling with regard to this accident was made the more acute because of the fact that the particular grade crossing involved had been ordered eliminated 17 months prior to the time the accident occurred, but no work had been done because of litigation instituted by the railroad companies.

As a result of the feeling which was aroused, the governor of the state presented a special message to the legislature on 3 March 1924, pointing out the inadequacy of the state's program with relation to the elimination of grade crossings, and stressing the need for greater action. At that time he outlined a plan which had been urged by the commission, calling for an amendment to the state constitution, creating state funds for elimination work, and permitting the state to loan money to the railroads and municipalities to bear their respective shares of the cost of carrying out the work. In this plan the entire work could be financed in the first place by the state, which would be repaid by the railroads and the municipalities for their respective shares, in annual installments.

In 1925, as a result of the efforts of those interested in the above plan, the subject of eliminating railroad-highway grade crossings received recognition in the state constitution through the adoption by the people of an amendment authorizing the creation of a debt by the state, not exceeding $300 000 000, to provide money for eliminating grade crossings. In this same amendment it was provided that such work be done under state supervision, and be paid for in the ratio of 25 % by the state, 25 % by the city, town or village, and 50 % by the railroad company.

Investigation made of crossing problem.

During the same year, a joint legislative committee was appointed to investigate the entire question of the elimination of grade crossings within the state. In the report of this committee, which was presented in 1926, it was pointed out that there were at that time, 7 504 main-track grade crossings in the state, and that in the opinion of the chairman of the Public Service Commission, at least 4 000 of these crossings should be eliminated. Continuing, the report divided the grade crossings in the state into three classes, A, B, and C, according

to the extent and nature of the traffic on the railroads and the highways, and gave the estimated approximate cost of the elimination of the various classes of crossings. One thousand, nine hundred and seventy-two crossings were placed in class A with an approximate cost of elimination of $281 810 000; 2 548 crossings were placed in class B with an approximate cost of elimination of $166 million 760 000; and 2 984 crossings were placed in class C with an approximate cost of elimination of $155 325 000.

New grade crossing law.

As a result of the studies made, a law was passed in 1926 governing the elimination of all existing grade crossings of steam and electric railroads within the state, outside of the cities of New York, Buffalo and Syracuse, concerning which special statutes were enacted. The new law, which was known as chapter 233 of the laws of 1926, did not materially change the practices of the state with respect to grade crossing elimination work, but it did place certain limitations upon the Publice Service Commission with respect to the orders for elimination which it might make. In this respect, it provided that the commission could not make an order which would require a municipality to pay back to the state in any one year a sum which would be in excess of 1/20 of 1 % of the assessed valuation of the taxable property of the municipality according to its last assessment roll. In other words, the effect of this provision was that the commission was prohibited from making an order which would result in an increase of one-half mill per annum in the tax rate in any municipality. Provision was made, however, in three ways, to take care of eliminations where the increase in the tax rate would be above that specified : by giving municipalities the power to express their desires by a vote of the people, by securing aid from the county in the form of a contribution, or by making the elimination a county project, in which event the county would pay the entire share of the community. This brought the county into the subject of grade crossing elimination for the first time, since the constitutional amendment adopted in 1925 did not include the county as a unit.

Another important change in the procedure of grade crossing elimination was brought about by the new law, whereby the supervision of all construction work was placed under the State Department of Public Works, while all financial matters were transferred to the state comptroller.

Limitations found in new laws.

Immediately after the passage of chapter 233, which was the first grade crossing elimination law, the commission adopted an initial program of crossings to be eliminated, and created a separate grade crossing bureau in the engineering division of the commission, under the supervision of the chief engineer. This initial program consisted of 108 projects, involving 174 crossings which were scattered widely throughout the state and distributed equitably over the various railroads. Hearings were started on these projects, but it soon became apparent that the provisions of the law relating to that part of the financing by municipalities would seriously limit the progress of grade crossing work. This was due to the limitation placed on the increase of the tax rate allowed in any municipality, and while the act provided that a town or village could elect to assume a burden in excess of the limitation set, or could secure aid from the county, there were only five instances of such favorable action, and in most cases, therefore, it was necessary to abandon elimination proceedings.

Recognizing this barrier to eliminat-

ing grade crossings which confronted many towns and villages with burdens far in excess of their capacity to pay, even under the liberal terms for refunding the money which was to be borrowed from the state, a constitutional amendment was passed in 1927, amending the first constitutional amendment with reference to the creation of a state debt for the elimination of grade crossings. This new amendment, which is in force at the present time, relieved cities, villages and towns from paying for any portion of the costs of grade crossing elimination work, and made the county the unit to bear the cost, other than that chargeable to the state and railroad companies. During this same year, the first grade crossing elimination law (233), was amended by chapter 445 of the laws of 1927, which was designed primarily to remove the doubt which existed as to the jurisdiction of the Public Service Commission in the case of certain crossings. The new act also made definite provision with regard to the procedure for drawing up programs of elimination projects for each year.

Following the enactment of the new grade crossing law, new proceedings were started in connection with 60 projects involving state and county highways, but progress was delayed considerably owing to the uncertainty which arose concerning the effect of the new constitutional amendment shifting the municipalities' share in grade crossing work to the counties. The main source of delays encountered, however, was in connection with the acquisition of the lands and easements required in connection with specific projects. This latter difficulty, and a number of other obstacles in the way of speeding up grade crossing elimination work, were remedied by an act, which became a law in March 1928, known as the « Grade Crossing Elimination Act » Chapter 678 of the laws of 1928. Under the provisions of this law, and the amendment to the constitution in 1927, all grade crossing elimination work within the state is now carried out.

$300 000 000 provided for elimination work.

Under the specific provisions of the constitutional amendment the legislature is authorized to create debts for the state not exceeding $300 000 000 in the aggregate, to provide money for the elimination, under state supervision, of highway-railroad crossings at grade. The amendment also provides that the costs of this work shall be borne in the ratio of 50 % by the railroad companies, and the remaining 50 % by the state and the county in which the crossing is located or by the state and the city in which the crossing is located if the city contains two or more counties.

Under the power granted to it in the above provisions, the legislature, by special legislation, was authorized to cover the debts incurred in grade crossing elimination work by the sale of state « grade crossing bonds », to be issued and sold by the state comptroller from time to time as might be required. The grade crossing elimination act also fixed the division of costs of elimination work other than the 50 % required to be paid by the railways, by providing that in all elimination projects, the state shall pay 40 %, and the county or counties in which a crossing is located shall pay 100 %. Provision was also made that where two or more counties or two or more railroad companies are involved, the cost to each shall be determined by the Public Service Commission, to the end however, that the railroads together shall pay 50 % of the costs, and that the counties together shall pay 10 % of the costs.

Elimination programs prepared each year.

In carrying out grade crossing work in the state, two state bodies are principally concerned; the Public Service

Commission and the Department of Public Works. The first of these bodies is quasi-judicial in character, while the latter is primarily supervisory in capacity. In addition to these two bodies, the state comptroller also plays a part, and has charge of all financial matters in connection with grade crossing elimination work.

The first step in the practices of the state with regard to the elimination of its grade crossings is the formulation of a program of eliminations to be considered during the ensuing calendar year. The Department of Public Works is required to file with the Public Service Commission, on or before 1 October of each year, a list of crossings, the elimination of which it suggests for consideration during the ensuing calendar year. This list is based upon a comprehensive study of the crossings of the state, and in formulating the list, an attempt is made to spread the work over the state as a whole and to divide it equitably among the various railroads, giving due consideration to any grade crossing elimation work which may already be under way. At the same time the railways and municipalities are given an opportunity to file similar lists if they so desire. All of these lists contain the names of the crossings, the names of the railroads crossed, the counties, towns, cities and villages in which such crossings are located and an estimate of the cost of eliminating each of the crossings, based upon the most practical method of effecting the elimination.

After giving due notice to the Department of Public Works, the railroads and the counties and municipalities affected. the Public Service Commission holds public hearings upon the lists of crossings suggested, together with such additional crossings as the commission may think, for various reasons, should be considered. At these hearings all parties are given an opportunity to be heard, and the railroad companies and counties are required to state whether they will avail themselves of state aid.

Upon the completion of these hearings, and not later than 1 December of the same year, the commission, from the information at hand, designates by order a definite program of crossings, the elimination of which will be condered during the following year. In framing this order, care is exercised by the commission to provide for the most effective elimination work, and at the same time, to spread it equitably over the state and among the different railroads. The commission is empowered to amend this general order from time to time as it sees fit, and serves copies of the order upon all those concerned, including the railroads.

Following the serving of this general program order, the commission holds hearings on the individual elimination projects included in the program, and makes orders stating the specific manner in which the elimination shall be accomplished in each case.

Railroads do most of actual work.

The orders of the commission direct the Department of Public Works, the railroad company or the county affected, to prepare plans, specifications and estimates covering the cost of the elimination work, the plans to show specifically that part of the work which, when completed, shall be maintained by the various parties concerned. After such plans, specifications and estimates have been submitted to and approved by the commission, the railroad company concerned is required to perform the work involved, exclusive of the highway approaches, and the Department of Public Woks is required to perform the work relating to the approaches unless the commission directs the railroad company or the county to do the latter work. If a railroad company

does not desire to undertake the specific work assigned to it, it may request that the work be performed by the Department of Public Works, and the commission may so direct. All of the actual work of construction in connection with grade crossing eliminations in the state is carried out under the general supervision of the Department of Public Works, and in accordance with the orders of the commission with respect to clearances, grades, visibility, etc.

If a railroad company or any of the other parties involved in a specific elimination project desires to make changes or additions in connection with the work, other than those strictly necessary for the elimination, such changes or additions must be shown by plans and be approved by the commission after a hearing with reference to such changes and additions. When such a condition arises, the order of the commission gives the estimated cost of the desired changes or additions, and also, the division of the expense incident thereto.

With the preliminary proceedings out of the way, the commission directs the manner in which the work is to be done, whether by contract or by the direct employment of labor and the purchase of materials, and authorizes the railroad company or the Department of Public Works, or both, as the case may be, to let such contracts as may be involved. All proposals of contractors are submitted to the commission, which has the power to reject bids which it may deem excessive.

Upon the awarding of any contract affecting a specific project, certified copies of the contract are filed with the other parties concerned, and the work can then begin according to the plans, provided the necessary land, if any, has been acquired. If it is found advisable to change the plans during the course of the work in the general interest of the elimination project, it is necessary for that party requesting the change to submit revised plans and estimates to the commission for its approval. If the commission approves the change and estimates, the work is allowed to proceed on the new basis, and, in the event that the change involves additional costs, such increased costs are prorated among the three parties concerned, on the same basis as the general cost of the elimination work.

Method of paying for work.

The proceeds of state grade crossing bonds are used in the first instance to pay the costs of all elimination projects ordered by the Public Service Commission, unless in specific instances, the railroad companies or the counties elect to pay their share directly from their own funds without the aid of the state. Such election on the part of a railroad company or a county must be filed with the commission within 30 days after the issuance of an order directing an elimination project, unless the commission allows an extension of time.

A number of the railroads have found themselves in a position where they cannot take advantage of state aid. This is because of the fact that the amount which they borrow from the state becomes a prior lien on their property and these companies believe that borrowing under such conditions is inadvisable in view of existing mortgage conditions on their properties. Hence, several of the larger roads are not taking advantage of the state loan provision, among these being the New York Central, the Lehigh Valley and the Long Island.

Upon the completion of an elimination project, and its approval by the commission, the state comptroller computes the proportionate share of the cost to be borne by each of the parties concerned, and determines the manner in which payment shall be made. After a hearing, at which those interested are

heard, the comptroller makes a final determination with regard to the division of the costs and the manner of making payments.

In the event of the failure or refusal of a railroad company to pay the amount or amounts specified in such a statement, and at the times prescribed, the amounts due, according to the law, can be apportioned to the several towns and cities in the county in which the crossing is located, according to the assessed valuation of the real property of the railroad, and placed on the respective assessment rolls of such towns and cities, which, in turn, can issue warrants for collection. It then becomes the duty of the towns and cities concerned to collect the amounts due from the railroad company in the same manner as other taxes are collected, and when collected, to pay the same to the county treasurer, who, in turn, must turn the money over to the state treasurer.

Acquisition of lands and easements.

The acquisition of lands necessary in connection with grade crossing eliminations is now accomplished by appropriation by the state under the provisions of the new grade crossing elimination act. Under this act, the Public Service Commission approves and the Department of Public Works files in the office of the Department of State, an accurate description and map of any lands which are deemed necessary in connection with the elimination of any crossing, whereupon the state may immediately take possession of such land for carrying out the elimination work.

Property owners affected are given full protection under the law in the determination of the value of property appropriated, and in the collection of legal damages, but any proceedings which may be instigated do not prevent the use of the land and the progress of the grade crossing elimination work. All awards or judgments in connection with the acquiring of lands, including all costs such as those incurred in the making of surveys, the preparing of descriptions and maps, the serving of notices of appropriation, etc., are considered as part of the cost of the elimination project, and are paid for by the parties concerned in the proportions prescribed for the entire work.

Appeal is only recourse of aggrieved.

The sole protection of a railroad company or a municipality against orders or decisions of the commission in connection with the elimination of grade crossings, is through the medium of appeal. The law provides that any party aggrieved by any order or decision provided for in or growing out of the grade crossing act, may, within 30 days after the service of an order or decision, apply to the Public Service Commission for a hearing, or in the case that a hearing was held prior to the making of such an order, for a rehearing, as a result of which the order causing grievance may be set aside, modified or affirmed. The law also provides that any party aggrieved, may appeal from an order or decision to the Appellate division of the Supreme Court which has jurisdiction over the particular area in which the grade crossing is located, and furthermore, to the Court of Appeals, in the same manner, and with like effect as is provided in the case of an appeal from an order of the Supreme Court.

All of the foregoing with regard to grade crossing elimination work in New York has reference only to grade crossings within the state, outside of the cities of New York, Buffalo and Syracuse. In recognition of the fact that grade crossing elimination work within these larger cities is influenced or affected invariably by many factors peculiar to the cities themselves, separate laws were

enacted to cover the elimination of grade crossings within these three cities. These special statutes confer jurisdiction as to construction upon a commission, known as the Transit Commission in the case of New York, and upon the special grade crossing commissions in the other two cities, but in each case, the work within these three cities is related closely to the general grade crossing elimination work of the state, and the parties involved are allowed the assistance in financing provided by the $300 000 000 state bond issue.

In addition to the policy of the state for the elimination of grade crossings by the separation of highway and rail traffic, as provided for in the constitutional amendment and the grade crossing elimination act now in force, a large amount of attention has been given by the Public Service Commission, under provisions of the grade crossing elimination act, to the closing of existing crossings which are relatively unimportant, and a number of orders closing such crossings have been the results. In this work, however, the commission has encountered serious difficulties, brought about mainly by the objections of local parties interested in keeping the crossings open.

During the past year the railroads of the state have suggested a number of crossings which should be closed permanently, and certain of these have been placed on the commission's program for 1929 for consideration. It is expected, however, that in most instances, great pressure will be brought by local interests in an attempt to prove that the public welfare does not require the closing of the crossings.

Much attention is also being given by the commission to many existing undergrade and overgrade crossings with the idea of making them safer by certain changes or alterations, as provided for under section 91 of the Railroad law of the state. Under this section, a railroad company or the proper authorities of a municipality, town, county, or the state, may bring a petition in writing to the commission, alleging that public safety requires alteration of a certain crossing, its approaches, the method of crossing, the location of the crossing, a change in the existing structure by which such crossing is made, or even the closing and discontinuance of the crossing and the diversion of highway traffic thereon to another street, highway, or other crossing.

After due consideration of such petitions, and public hearings, the commission determines what alterations or changes, if any, shall be made. However, any orders made by the commission under this law are based on the assumption that funds are available and that no recourse is to be made to state aid through the $300 000 000 bond issue. Whenever a change is to be made in an existing crossing or structure under this law, the commission designates under whose authority the work will be done, and 50 % of the expense is borne by the railroad company, while the remaining 50 % is divided between the municipality, town county and state, or any of them depending upon the unit or units having jurisdiction over the street or highway involved.

Under other provisions of the Railroad law, increased caution is also being exercised with regard to the opening of new crossings, whether by the construction of new railway lines or new public thoroughfares. Sole right in this matter is vested in the Public Service Commission, which can refuse petitions for new crossings at grade by directing that the new crossings shall be above or below grade. Wherever a new railway is constructed across an existing highway, the entire expense in connection with the crossing involved must be borne by the railroad company. On the other hand, when a new highway is constructed

across an existing railroad, the railroad company concerned is required to pay one-half of the cost of the work involved, and the remaining 50 % is borne by the municipality, except in the case of state and county highways under the jurisdiction of the Department of Public Works. In the case of state highways, the whole 50 % is borne by the state, while in the case of county highways, the 50 % is divided between the state and the county in the same proportion as the original construction cost of the highway was borne.

Present policy is bringing results.

As a result of the old policy of the state, a total of 529 grade crossings had been eliminated up to and including 1925, this total not including those crossings eliminated within the cities of New York and Buffalo. During 1925 alone, in which the old policy of the state was still in effect, 16 grade crossing projects were completed, which involved the elimination of 39 crossings. In addition, four crossings were changed or altered under the provisions of the Railroad law.

In 1926, after the passage of the state referendum with regard to the bond issue, and the grade crossing elimination law, the commission adopted an initial program of crossings to be eliminated, which included 108 projects involving 174 crossings. Owing to the difficulties of financing under the statutes at that time, many of the projects included in the initial program were dropped, but before the year was over, 116 additional projects, representing 307 crossings, had been added to the program. While many projects were started during that year, only three crossings were actually eliminated under the new laws. In addition to these, however, 14 crossings were eliminated and 3 were altered during the year under the provisions of the Railroad law.

In 1927, while still laboring under the difficulties of financing and delays brought about through the procedure necessary at that time in connection with the acquisition of lands and easements, the commission issued orders directing the elimination of 167 crossings, and within that year 50 crossings were actually eliminated. In addition, 10 crossings were eliminated and 9 crossings were altered during that year, under the provisions of the Railroad law.

The program of the commission for 1928 included 174 projects, involving the proposed abolition of 203 crossings, which it was estimated would cost approximately $30 867 000. During the year 24 additional projects, representing 61 crossings and estimated to cost $2 million 575 000 were added to the program. During that year, 52 crossings were actually eliminated under the provisions of the grade crossing law, and in addition, 1 crossing was eliminated and 14 crossings were altered under the provisions of the Railroad law.

One hundred and thirty-nine additional projects, involving the elimination of 246 grade crossings in the state, outside of greater New York, Buffalo and Syracuse, were designated by the Public Service Commission for consideration during 1929. The total estimated cost of these eliminations is $31 123 700, of which the state's share is set at $12 million 449 480, the counties' share $3 million 112 370, and the railroad companies' share $15 561 850. Thirty-three elimination projects involving 54 crossings, which were under consideration on the 1928 program, but upon which no determination had been made, were also continued on the 1929 program. The total estimated cost of these projects is $8 million 391 000, of which the railroad's share is $4 195 500.

The projects on the program involve 20 railroads. Forty-one of the projects are on the New York Central, with the

road's share of the estimated cost set at \$5 173 500; 19 projects are on the Delaware & Hudson, with the road's share of the cost \$1 176 400; 19 projects are on the Erie, with the road's share of the cost \$1 491 400; 13 projects are on the Lehigh Valley, with the expense to the road set at \$1 185 500; and 12 projects are on the Long Island, on which the road will be required to share \$3 436 500 of the cost. On 1 January 1929 there were 52 eliminations under contract involving an estimated expenditure of \$4 654 000.

[625. 245 (.42)]

CURRENT PRACTICE.

Conveyance of large transformers.

Fig. 1, p. 2387.

In connection with the national electricity schemes, it has been necessary to transport a number of large electrical transformers, and to cope with this traffic, the London North Eastern Railway Company in November, 1928, constructed a special wagon at their Locomotive Works, Darlington, to the design of Mr. H. N. Gresley, Chief Mechanical Engineer. This special wagon consisted of two main girders and pivotal bolsters mounted on two existing six-wheeled 40-ton flat wagons, this expedient being resorted to in order to meet the urgent requirements then existing, time not permitting of new wagons being built. This wagon was restricted to loads up to 66 tons in weight.

The girders and pivotal bolsters were designed to carry distributed loads up to 70 tons in weight, and in July of this year were removed from the 40-ton flat wagons and mounted on two double bogie trucks, thus improving the axle loading and allowing the maximum load to be carried.

The width between the main girders is adjustable and loads up to 19 feet long and from 3 feet to 7 ft. 6 in. wide can be accommodated.

The wagon has been specially designed to facilitate loading and unloading where crane power is not available. The unloading procedure is as follows; the weight of the transformer is first taken by lifting jacks and packings and the side girders are moved laterally by means of the adjusting screws. The two

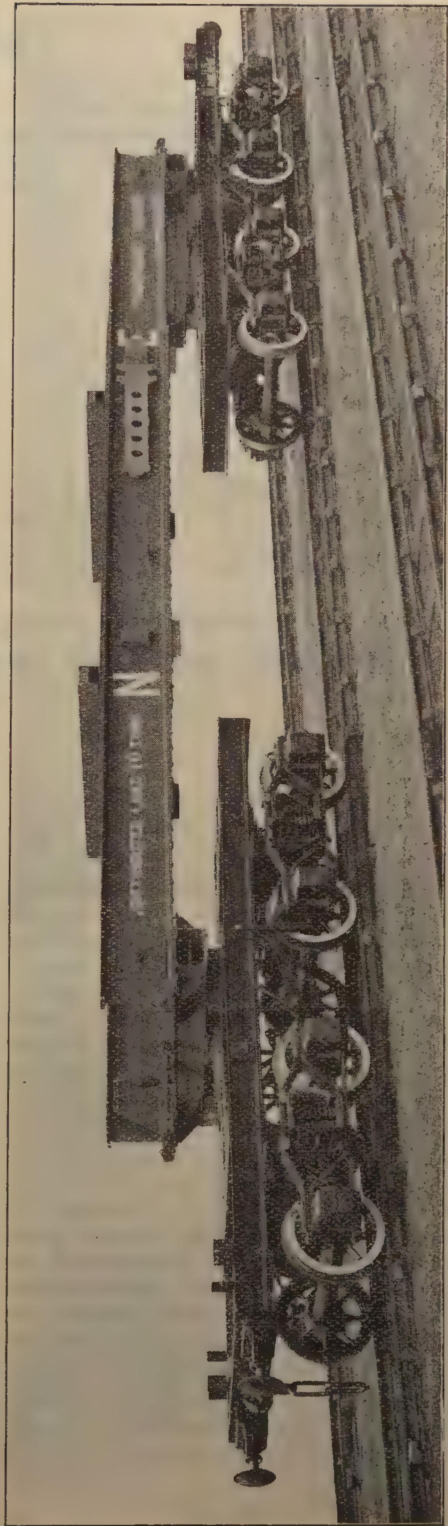


Fig. 1.

rolling struts with which the set is provided are then fixed in position and the main supporting bolts removed, thus enabling one carrying wagon and the girders to be drawn clear of the load.

The following are the principal dimensions :

Length over buffers . .	65 ft. 6 in.
Length over headstocks .	62 ft. 6 in.
Centre to centre of carrying trucks	20 ft. 6 in.
Length between trucks. .	20 ft.6 in.
Maximum length of transformer to be conveyed .	19 ft. 0 in.
Buffer height	3 ft. 5 1/2 in.
Diameter of wheels on tread	2 ft. 9 in.
Maximum width over main girder.	9 ft. 0 in.
Maximum width between main girders	7 ft. 6 in.
Minimum width between main girders	3 ft. 6 in.
Height to top of main girders	7 ft. 9 5/8 in.
Height to top of transverse securing girders . . .	8 ft. 5 5/8 in.

The tare weight of the complete wagon set is 40 tons.

[625. 258 (.42) & 656 .212.5 (.42)]

The first British marshalling yard to be equipped with rail brakes (Frölich), Whitemoor near March, London & North Eastern Railway.

Figs. 1 to 4, pp 2389 to 2393.

Since the installation of car retarders at the Gibson Yard of the Indiana Harbour Belt Railway (United States) in 1923, the British railways have been studying the adaptation to their own particular set of conditions, of such a system of automatic braking of wagons descending from the hump of marshalling yards.

In Germany, Wustermarck, Cologne (Nippes) and Seddin marshalling yards were the scene of extensive trials with various types of rail brakes, commonly known in America as car retarders. It was felt, however, that with the small size of the British wagon, with an average of approximately 10.5 tons capacity and a tare, or unladen weight, of 5.5 to 6.0 tons, according to the type, the problem was essentially different from that which presented itself in the United States, where 45 tons is the approximate capacity of the average freight car; even in European continental countries, the wagon of twenty-ton capacity is rapidly becoming standard. The report of Mr. C. R. Byrom, O. B. E., Chief General Superintendent, London, Midland and Scottish Railway, to the coming International Railway Congress meeting at Madrid, entitled « Methods to be used in marshalling yards to control the speed of vehicles being shunted and to ensure that they travel on to the lines in the various groups of sidings », which deals fully with this problem of braking wagons in marshalling yards in Great Britain, appeared in the June 1929 issue of the *Bulletin of the International Railway Congress*. It is not, therefore, considered necessary to give any further information concerning this question.

In view of the low costs involved per wagon in passing wagons through British marshalling yards, no adequate case has so far been made out for the installation of rail brakes in any existing yards, although many such schemes have been the subject of close study.

The London and North Eastern Railway, was faced with a totally different problem in the construction of the new yard at Whitemoor, near March.

This marshalling yard was designed to deal with traffic flowing from the North and West to the South and East, as the sketch plan (fig. 1) demonstrates.

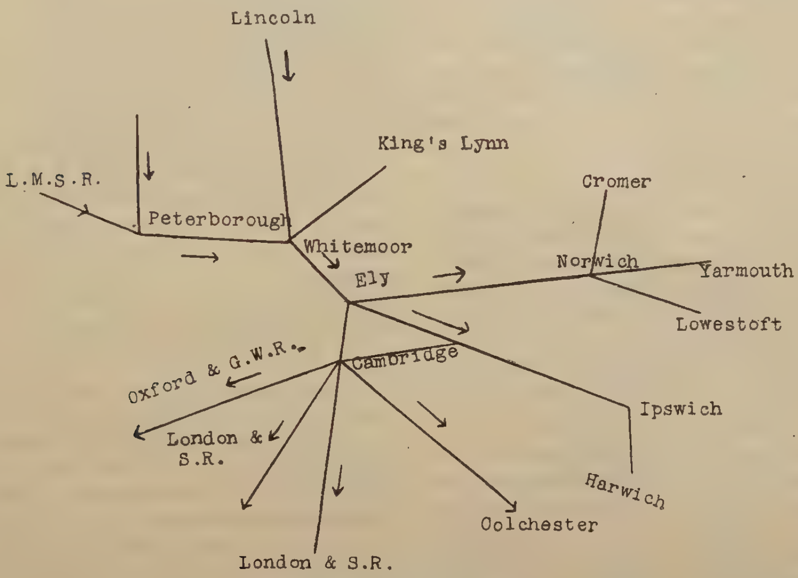


Fig. 1.

It was hoped to concentrate at the new yard the shunting work which was being accomplished at many centres situated to the South and East, to arrange the wagons in such order that shunting work entailed by trains departing from Whitemoor would be reduced to a minimum, and to route additional traffic through Whitemoor so as to relieve sections of main line which were most suitable for high speed express passenger trains and fast long distance freight trains fitted with continuous brakes.

The previously existing facilities at Whitemoor have now been wholly allocated to traffic from the South and East flowing to the North and West, much of which consists of empty coal wagons. Similarly the new yard for traffic from the North and West consists of coal traffic to the extent of about 60 %, although there is an important proportion of general merchandise traffic including a heavy tonnage of bricks originating in the Peterborough District.

After very detailed studies had been made of the comparative advantages of manual braking of wagons as opposed to one of the several types of automatic rail brakes such as had been installed in Germany and the United States, it was determined that the Frölich design of rail brake as in existence at Hamm Yard (Germany), the Eastern entry to the Ruhr coalfied, would be likely to prove the most suited to British railway operating conditions. It was realised that in all probability certain difficulties would arise in the first adaptation of a foreign apparatus to British conditions, and in practice the aims which it was hoped to achieve by the construction of the new yard have not yet been fully

attained, but most valuable experience has been obtained from this pioneer installation.

Whitemoor Yard was opened for traffic in April 1929 and on a typical day during its first month of operation 2 982 wagons were dealt with involving no less than 2 106 « cuts ». Approximately 60 trains are made up in the yard per day, which is equivalent to a train departure every 24 minutes throughout the 24 hours.

In a paper read before the Institute of Transport (London) in March 1929 by Mr. H. N. Gresley, Chief Mechanical Engineer of the London and North Eastern Railway, the author exhibited two sketches showing the change in the hump gradient necessitated with the adoption of the Frölich rail brake system.

If maximum use is to be made of the steep gradient it is essential that the « Balloon system » of point lay-out (fig. 2) be chosen in place of the older « Ladder system » (fig. 3). It will be realised that with the balloon design the distance between the base of the hump and the fouling point on the various sorting sidings is approximately the same. The Frölich rail braking method enables the speed of the wagon to be increased with a resultant increase of the wagon capacity of the hump. This is achieved in spite of an important reduction in cost consisting primarily of wages and reduced locomotive mileage.

Through the elimination of hand braking of wagons the risk of danger to employees is minimised; it is also claimed that damage to wagons and their contents is also reduced, with a resultant reduction of claims.

It is a tribute to the excellence of the brake design that at Hamm it is customary to handle wagons carrying the most fragile freight, such as livestock, over the hump, while the available brake power is sufficient to bring to a stop without derailment a train of sixty loaded wagons.

When the design of the new yard was under consideration the possible utilisation of hand- or mechanically operated skids or shoes was suggested, of the Deloison type as used at Lille (La Délivrance), Nord Railway, but it was felt that no existent design of shoe could attain similar results to those outlined above.

Whitemoor Yard, as will be seen in the plan (fig. 4) consists of ten reception sidings with one single track over the hump feeding no less than 40 sorting sidings, the speed of the wagons into these latter being controlled by means of four hydraulic rail brakes operated from a single control cabin.

A shunting list is made out by a shunter for every train on its arrival at the reception sidings, to show into which sorting siding the wagons are to be placed. As the shunter walks along the train he uncouples the wagons. Several copies of the shunting list are made out, three being despatched by pneumatic tube to the control cabin, others being utilised in the shunter's cabin at the top of the hump.

In the control cabin there are three men on duty in each shift, namely two brake operators and a point operator. Each brake operator controls two rail brake units, and he knows the line destination of each cut, whether consisting of one or perhaps twelve wagons, from the copy of the shunting list despatched to him from the shunter's cabin on the hump.

Naturally it requires considerable practice and experience before absolute precision can be obtained, and the situation is made more difficult in Great Britain by the fact that many wagons are still in circulation fitted with grease axle boxes. Such wagons do not run so freely as the modern type equipped with oil axle boxes, hence the work of the brakesman is made more difficult than

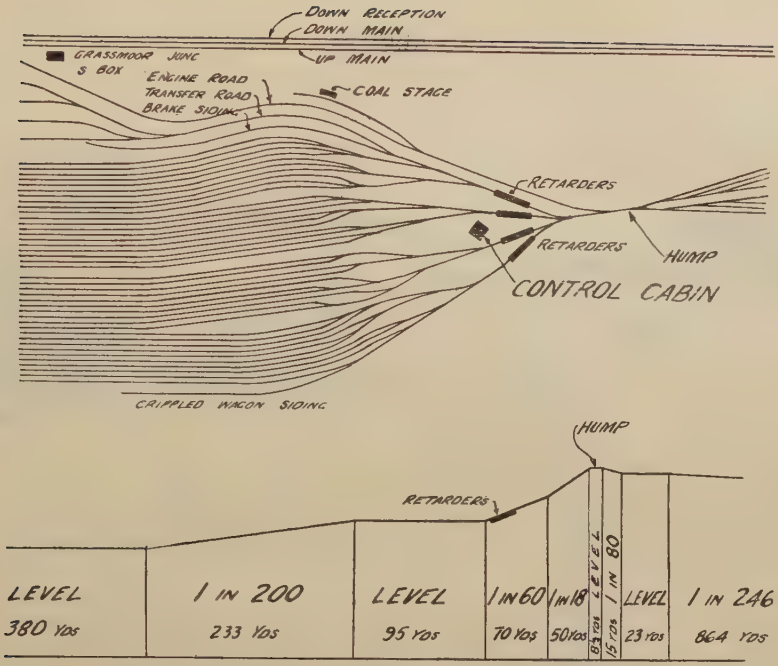


Fig. 2. — London & North Eastern Railway, Southern Area.
Whitemoor Up marshalling yard, balloon system.

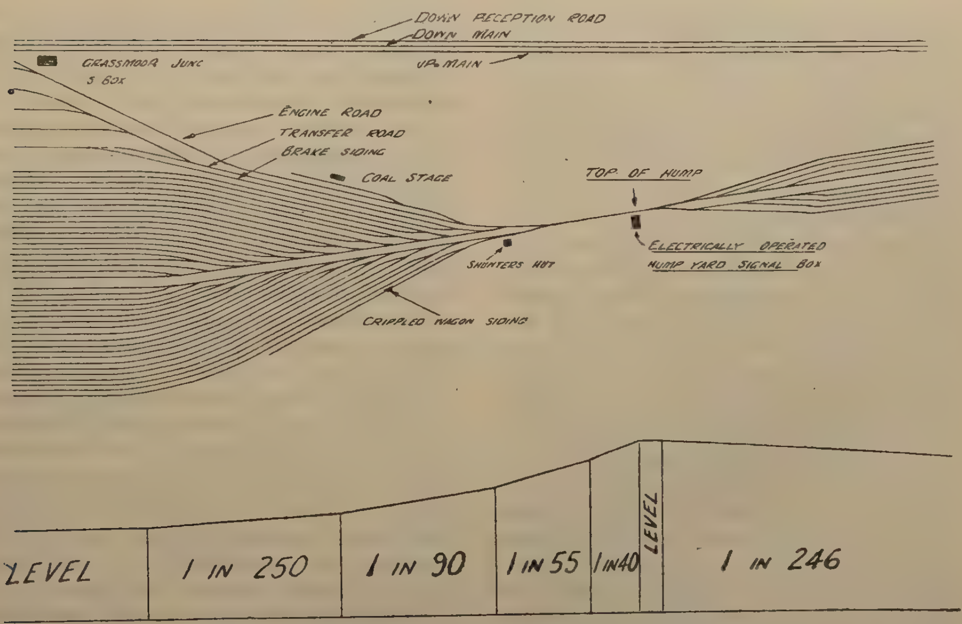


Fig. 3. — London & North Eastern Railway, Southern Area.
Whitemoor Up marshalling yard as designed to include ladder system.

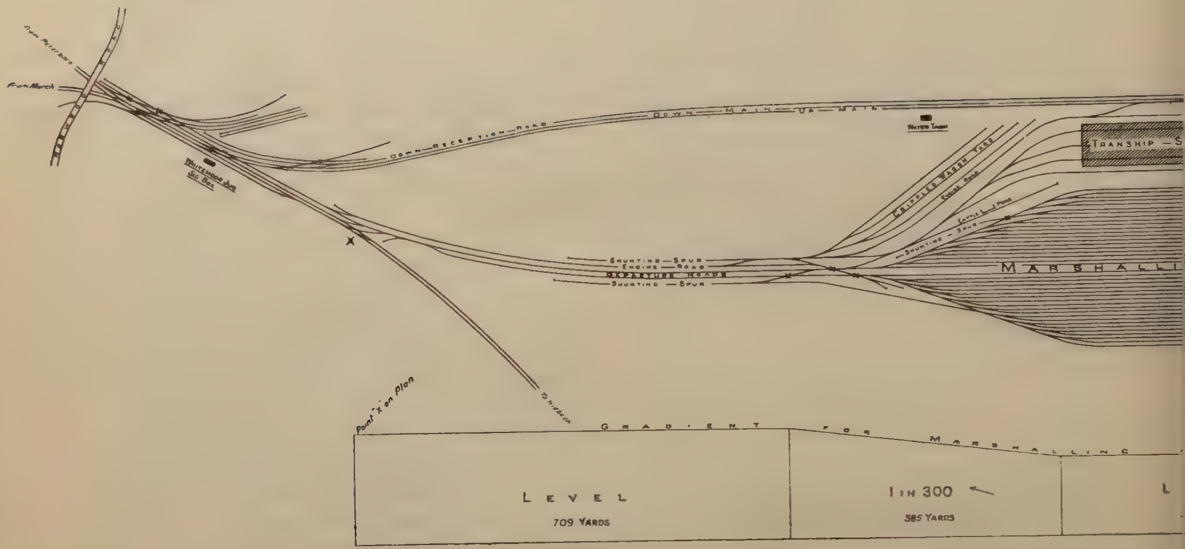


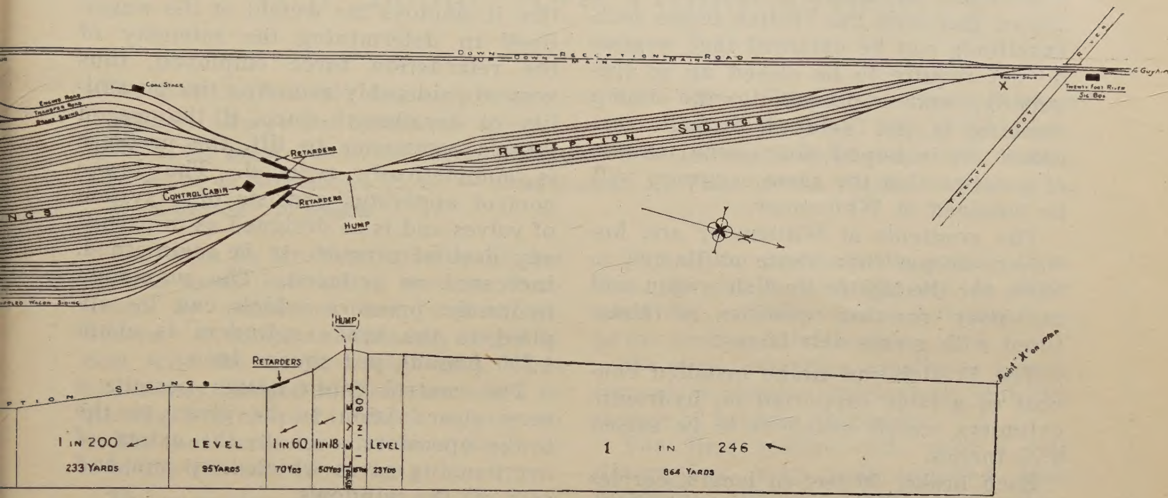
Fig. 4. — London & N
Diagram of Wh

is the case on the Continent of Europe or in the United States, where there is less variation in the running capacity of the different wagons.

The third copy of the shunting list to be received in the control cabin is used by the point operator who is seated at a table.

Whitemoor has been equipped with seven automatic king points controlling eight groups of sidings. These points are operated mechanically through collector drums by separate route levers and are set up previous to the commencement of the train being humped. Each « cut » of wagons sets the route correctly for the succeeding « cut » by means of track circuits, and so on, for the whole, say, 80 wagons of a train. The routes chosen are stored by means of a set of collector drums, a machine produced by the Allgemeine Elektrizitäts Gesellschaft. Thus the operator, by merely operating levers in correct sequence, can set up all the routes so far as the seven automatic king points are concerned for a whole train before it is humped. By the time the wagons have reached the next set of points they are sufficiently spread out to permit the operator to control them individually. The original routing is of course set up in accordance with « cut » sequence as set out upon the copy of the shunting list received by the operator, and the apparatus is so designed that if, for any reason, the route setting has to be cancelled, such cancellation can be effected whenever desired. Points other than the seven controlled by the track circuited lengths of rail are electrically operated by hand switches on the table in front of the operator. This table is suitably equipped with point indication lamps giving the point position, while other lights applying to each point are illuminated when a wagon passes over them.

It will be appreciated that the speed of trains over the hump must be regular, and in order to achieve the desired rate



ilway, Southern Area.
'shalling yard.

of 3 to 3.5 miles per hour, precision speedometers have been installed on the three-cylinder locomotives, specially designed for hump shunting which have been allocated to this service. It has not been considered necessary to fit these locomotives with the added refinement of wireless receiving sets which enable the foreman shunter to give instructions to the engine driver whilst in process of humping, but colour light signals and electric hooters have been put into service to bring about effective control.

It is essential if such a system is to function satisfactorily and maximum utilisation be obtained from the hump, that the movement of the king points be very rapid in view of the close proximity of the succeeding « cuts ». The track circuits, consisting of insulated lengths of rail which control these points at Whitemoor, are 38 feet in length, and the point movement occupies not more than 0.7 second.

A staff of four or five men is employed in the sorting sidings, and it is their duty to couple up wagons as they arrive on the respective sidings. They are also available to stop any wagon which has not received sufficient retardation in the brakes. Such latter cases become progressively less as the skill and experience of the retarder operators increase. Unfortunately there exists a small proportion of British wagons equipped with wheels containing nuts and bolt heads on the interior surface of the tyres which cannot at the moment be retarded mechanically, but such wheels are of an old design and they are being steadily eliminated, and an additional braking rail is being put in to overcome this difficulty. In nearly every marshalling yard an important period of time is occupied by the humping engine or the locomotive arranging the wagons in station order at the departure end of the sorting sidings being required to push up the

wagons together on each sorting siding so that they can be coupled together. Experience at Hamm (Germany) has shown that with the Frölich brake such exactitude can be obtained that wagons do not require to be closed up so frequently, and consequently the hump working is not delayed through this cause. It is hoped after some months of practice that the same accuracy will be obtained at Whitemoor.

The gradients at Whitemoor are, however, steeper than those at Hamm, to allow for the lighter English wagon and the poor running qualities of those fitted with grease axle boxes.

The Frölich rail brake installed consists of a table supported on hydraulic cylinders which enable it to be raised 4.75 inches.

Each brake, 50 feet in length, carries two pairs of longitudinal rails, which are level with the top surface of the running rails when in the normal position. On being raised these braking rails exert pressure by means of a toggle action on both the outside and inside of the tyres of the wagons as they pass through the brake, thus producing a retarding effect upon the wheels. The amount of pressure applied by these braking rails is increased or reduced at will by the operator in the control cabin, and it has been found in practice that a wagon running at 15 miles per hour can be brought to a standstill within its own length.

Unlike the American and other types of car retarder, the Frölich design is claimed by its inventor to be unique in that it employs the weight of the wagon itself in determining the intensity of the retardation force employed, thus very considerably reducing the possibility of derailment since, if the wagon wheels commence to lift, the pressure is automatically reduced. The brake control apparatus consists of a system of valves and is so designed as to permit any desired pressure to be maintained, increased or reduced. The maximum hydraulic pressure which can be applied to the brake cylinders is about 1 200 pounds per square inch.

The control cabin design permits a very clear vision to be given to the brake operators, even to the extent of overhanging eaves which keep sun and rain off the windows.

It remains to point out that Whitemoor Yard is fitted with flood lighting, the lanterns being equipped with concentration lenses and direction mirrors superimposed on poles 35 feet high, 23 in number and illuminating 200 000 square yards. It has been found possible to deal in this new yard with an 80-wagon train in eight minutes, whereas with ordinary braking eighteen minutes would not be considered excessive in a typical British hump yard.

12 August, 1929.

[624 . 02]

NEW BOOKS AND PUBLICATIONS

MENDIZABAL (DOMINGO). Engineer, Bridges and Roads Service. **Estudio y construccion de tramos metalicos** (*Design and construction of metal bridges*). Volumes 1 and II (7 1/2×10 1/4 inches). Vol. 1, 471 pages. Vol. II, 584 pages; 1285 figures in the text and 15 folded plates 1928, Madrid, Sucesores de Rivadeneyra (S.A.). — Artes Graficas, 20, Paseo de San Vicente. — Price of the whole treatise : 70 pesetas.

The work by Mr. Mendizabal is divided up into many interesting sections illustrated by numerous and well-chosen figures. A complete summary ought to deal with the whole book; we are unfortunately obliged to limit ourselves to quoting the chapters which appear to us the most original, and most likely to hold the reader's attention.

The beginning of the treatise on metal bridges is first of all devoted to the study of reticular systems; it is all well analysed and illustrated by clear and expressive designs. Following this, the author next recalls the differences of American and European conceptions of trellis bridges; we find in the book interesting facts about the calculation of articulations. Further on, following on this subject, the author shows, in a long chapter, the whole of the theory of secondary stresses, reviewing, in passing, the successive researches of Mohr, Ritter, Résal, and Waddell.

We already have an important and interesting work by Mr. Mendizabal on the different regulations in use for the calculation of railway bridges; we reviewed this book, some years ago, drawing attention towards the formula for impact, proposed by Mr. Mendizabal, which might be called « elliptic » formula (1).

The author again, in his present treatise, devotes a long chapter to these questions, as well as to the determination of the dead and live loads.

We draw attention equally to a very important chapter which deals with the design of bridges on curves.

The first volume ends with a full description, very well supplied with instructive figures, of the construction, and organic structure of metal bridges.

In the second volume, in which the interest is as well sustained as in the first, the author explains, in great detail with many well-chosen figures, the erection of metal bridges. There is, in this respect, it must be admitted, a gap in technical literature, which is happily filled by this chapter of Mr. Mendizabal.

This second volume contains also two chapters which are rarely found in a treatise of this type — those devoted to the maintenance, to the causes of failure, and to the reinforcement, of metal bridges.

The last and valuable chapters relating to cantilever bridges, which Mr. Mendizabal calls equilibrium bridges, to arch bridges and to opening bridges must also be mentioned.

Mr. Mendizabal's work is very valuable: we can express only one regret, that, being written in Spanish, it is to some extent closed to French and English readers.

R. D.

(1) See *Bulletin of the Railway Congress*, November 1926.

[385. (09.2]

OBITUARY

Léon MAURIS,

Chief Engineer of Bridges and Roads,
Honorary Chief General Manager and Vice-President of the Administrative Council of the Paris, Lyons & Mediterranean Railway Company,
Former member of the Permanent Commission of the International Railway Congress Association,
Delegate to the Paris (1900), Berne (1910), and Rome (1922) sessions of the Railway Congress.

It is with great regret that we have learnt of the death of Mr. Léon Mauris, which occurred on 24 June last.

Mr. Mauris was born in 1850 at Ruffey (Doubs).

He passed into the Polytechnic School in 1870 and afterwards, the School of Bridges and Roads.

In 1884, Mr. Mauris entered the service of the Paris, Lyons & Mediterranean after ten years of service with the Bridges and Roads. As Permanent Way Engineer at Marseilles he had an immediate opportunity of distinguishing himself on the occasion of the severe floods which ravaged the departments of the Hautes and Basses Alpes. When called to Lyons to be Head of the twelfth Division of the Permanent Way Department, he was chiefly concerned with the Saint-Etienne district where mining works were increasingly menacing the safety of the railway. He showed himself to be a good engineer and his chiefs marked in him a lucid and comprehensive intelligence enhanced by the highest moral qualities.

In 1888, Mr. Mauris was called to Paris and placed at the disposal of the Chief Operating Engineer. From this period dates important progress in the operating service, such as the inauguration of express goods trains and the construction of marshalling yards.

In 1894, Mr. Mauris who was then Assistant Operating Engineer, was made Assistant Chief Engineer for Permanent Way at Headquarters.

In 1899 he was appointed to the important position of Chief Operating Engineer. He had to face the difficulties resulting from the enlargement of the Paris station and the additional traffic due to the Exhibition of 1900.

Some years later, in 1902, he returned to Headquarters as Assistant General Manager. He had already been in the Company's service for more than twenty years and he had acquired a thorough knowledge of the railway system and of all railway problems; it was therefore with full confidence that the General Manager, Mr. Noblemaire, placed in his hands, in 1907, the burden of the office he himself had held so long.

He occupied the position of General Manager with great distinction for twelve years.

During the four years of the Great War his task was a crushing one and he had to deal with grave difficulties which he succeeded in overcoming.

Mr. Mauris became Director of the Paris, Lyons & Mediterranean in 1920 and Vice-President of the Administrative Council in 1925. He was also Director or President of several other railway companies, etc.

After forty-five years constant service, his strength began to fail at the beginning of 1929, and he died peacefully on 24 June.

He had been a Grand Officer of the Legion of Honour since 1919.

* * *

Mr. Mauris was nominated a member of the Permanent Commission at the closing meeting of the 8th session (Berne 1910). He resigned his mandate when he retired as a Director of the Paris, Lyons & Mediterranean.

He always evinced very great interest in the International Railway Congress Association.

We have tendered our sincere sympathy to the family of the deceased.

The Executive Committee.